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RIVER TOW BEHAVIOR IN WATERWAYS. REPORT 1. EXXON TEST PROGRAM.(U)

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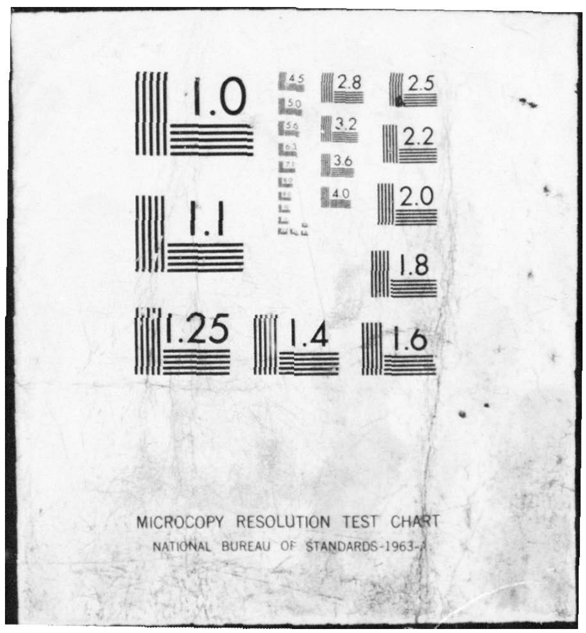
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LEVEL II

TECHNICAL REPORT H-78-17

RIVER TOW BEHAVIOR IN WATERWAYS

Report 1

EXXON TEST PROGRAM

by

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R. M. Schulz Associates
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October 1978
Report 1 of a Series

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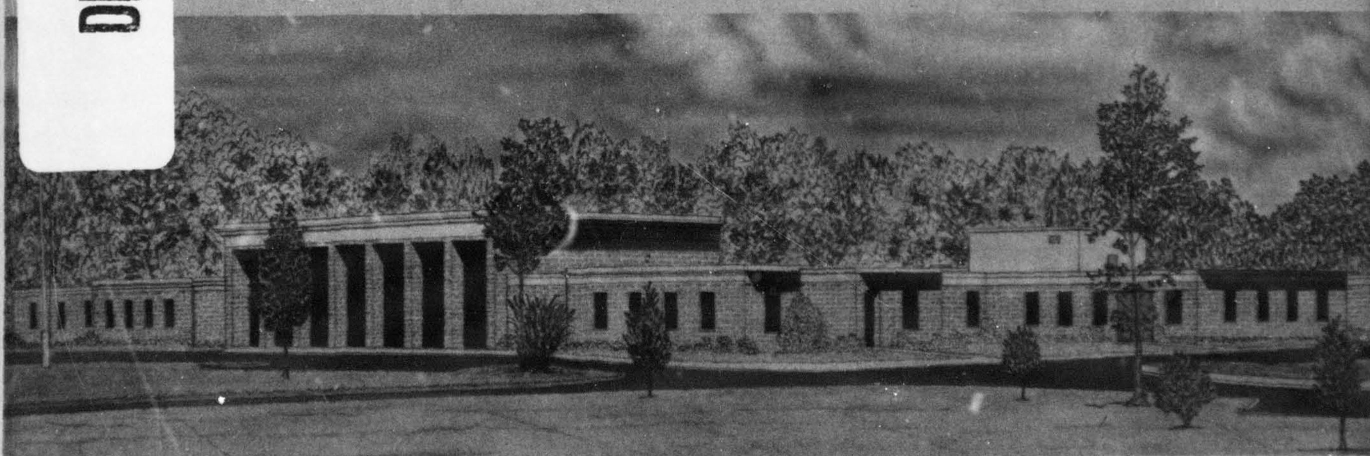

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Monitored by Hydraulics Laboratory
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This is the final report by R. M. Schulz Associates (RMSA) to the Corps of Engineers (COE) on the study to obtain and analyze river tow behavior data. This report describes the first full-scale tow test program conducted in this country in which second-by-second records of tow position, attitude, rudder, power, and river environment parameters are obtained and analyzed. The study demonstrates the feasibility of using off-the-shelf position fixing and rudder angle recording equipment to measure the dynamic behavior of river tows.

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20. ABSTRACT (Continued).

Study results, based on analysis of over 6500 second-by-second digital records of 42 test, tow, and waterway parameters, are summarized below.

1. Turns at half-power through 90^{o} of a 3250-foot radius river bend with a current of 2.2 feet per second show that: (a) average downstream drift angles are double upstream drift angles, (b) maximum drift angles are greater than 20^{o}, and (c) speed loss is almost 30 percent downstream and 13 percent upstream.

2. Zig-zag maneuvers at full power using about 10^{o} of rudder show that: (a) maximum drift angles and angular velocities are greater upriver than downriver, and (b) speed loss is at least 7 percent of initial speed.

3. With the tow moving at full power downriver, the minimum distance required to perform a "crash" stop is at least two tow lengths.

4. Speeds will fluctuate from 15 to 37 percent during constant power, straight course operation due to steering, current, and river bank and bottom effects.

5. A 15 percent port and starboard power imbalance on a twin screw towboat requires about 2^{o} of rudder angle to compensate.

6. Rudder angle measurements indicate that centerline stops for the steering rudders will improve underway efficiency.

7. Computerized tow performance data obtained from this study completely describe tow motions in the horizontal plane such that: (a) yaw, sway, and surge parameters may be used in traditional mathematical models of tow dynamics; (b) waterway and tow parameter interactions may be used to identify waterway design anomolies; and (c) pilot steering responses to observed accelerations may be used to evaluate self-propelled model tests.

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PREFACE

The project described herein was undertaken by the U. S. Army Engineer Waterways Experiment Station (WES) for the Directorate of Civil Works, Office, Chief of Engineers, U. S. Army. The project was conducted by R. M. Schulz Associates in cooperation with the Exxon Company under Contract No. DACN39-77-M-0625. This study was a pilot project to obtain tow performance data from full-scale field measurements of tow maneuvers. This test program is the result of an expansion of the original tow performance test program planned by the Exxon Company.

The study was conducted under the general supervision of Mr. H. B. Simmons, Chief, Hydraulics Laboratory, and Mr. M. B. Boyd, Chief, Hydraulic Analysis Division. The contract monitor for the project was Dr. L. L. Daggett, Math Modeling Group. Messers. C. J. Huval and T. D. Ankeny, Math Modeling Group, provided advice and assistance on this study. Acknowledgment is given to Messrs. F. Sharp and J. Lane, Systems Analysis Branch, Planning Division, Office, Chief of Engineers, for their support of this study.

Special acknowledgment is given to Messrs. R. Schulz, R. M. Schulz Associates; M. Bennett, Exxon Company; I. Douthwaite, Dravo Corporation; and E. Shearer, Hillman Barge and Construction Co., for their cooperation, assistance, and advice in planning and conducting this test. The Exxon Company's cooperation and their showing of data from these tests is greatly appreciated.

Commander and Director of WES during this study and the preparation and publication of this report was COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

FOREWORD

For several years the author has tried to interest companies and government agencies involved in inland waterway operations to study tow performance--first, to improve tow designs; and second, to improve navigation through better steering systems and more efficient waterway facilities. This report describes a pilot study which obtained tow performance data from a one-day series of tow trials conducted by Exxon Company in November 1976. The results described in this report should encourage others to undertake such studies.

Grateful appreciation is extended to several people who assisted the author in this work: Mr. Larry Daggett, of the Waterways Experiment Station, for his tireless efforts in the early stages of the program which were instrumental to the program's success; the entire Exxon organization for their splendid cooperation, in particular Mssrs. Bennett, Burke, and Olsen; Mr. Douthwaite and his colleagues at Dravo Corporation for sharing both test data and operational experience; and Mr. Shearer, Hillman Barge & Construction Co., for his assistance in compiling tow characteristics; and Mr. Bert Schulz, R M Schulz Associates, for his invaluable work during the field survey and trials.

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I. INTRODUCTION

This is the final report by R M Schulz Associates (RMSA) to the Corps of Engineers (COE) on the study to obtain and analyze river tow behavior data. This report describes the first full-scale tow test program conducted in this country in which second-by-second records of tow position, attitude, rudder, power, and river environment parameters are obtained and analyzed. The study demonstrates the feasibility of using off-the-shelf position fixing and rudder angle recording equipment to measure the dynamic behavior of river tows. Study results, based on analysis of over 6,500 second-by-second digital records of 42 test, tow, and waterway parameters, are summarized below.

- Turns at half-power through 90° of a 3250 foot radius river bend with a current of 2.2 feet per second show that:
  - average downstream drift angles are double upstream drift angles;
  - maximum drift angles are greater than 20°; and,
  - speed loss is almost 30 percent downstream and 13 percent upstream.

- Zig-Zag maneuvers at full power using about 10° of rudder show that:
  - maximum drift angles and angular velocities are greater upriver than downriver; and,
  - speed loss is at least 7 percent of initial speed.

- With the tow moving at full power downriver, the minimum distance required to perform a "crash" stop is at least two tow lengths.

- Speeds will fluctuate from 15 to 37 percent during constant power, straight course operation due to steering, current, and river bank and bottom effects.

- A 15 percent port and starboard power imbalance on a twin screw towboat requires about 2° of rudder angle to compensate.

- Rudder angle measurements indicate that centerline stops for the steering rudders will improve underway efficiency.

- Computerized tow performance data obtained from this study completely describe tow motions in the horizontal plane such that:

  - yaw, sway, and surge parameters may be used in traditional mathematical models of tow dynamics;

  - waterway and tow parameter interactions may be used to identify waterway design anomolies; and,

  - pilot steering responses to observed accelerations may be used to evaluate self-propelled model tests.

1.1 Study Background

In the latter part of November 1976, a river tow owned and operated by Exxon Company was instrumented and a number of trials were run to determine the tow's speed-power, fuel consumption, and maneuvering performance. The tests took place in the Baton Rouge area approximately between miles 230 and 235 on the Lower Mississippi. The test program was initially intended as a series of straight-course, speed power trials over a measured course to determine the propulsion efficiency of Kort nozzle and open-wheel propulsion systems. The first part of the program took place in November using a towboat fitted with Kort nozzles. The second part of the program was to use a sister design without Kort nozzles.

The November test program format was later expanded to include participation by RMSA under COE sponsorship to record and analyze measurements to tow position and steering behavior. The primary reason for expanding the test program was the need for actual tow behavior data to validate Waterways Experiment Station (WES) model testing programs and improve facility engineering and design capability.

The Exxon program provided a cost-effective method of gaining experience in conducting full-scale tests using position fixing equipment to obtain measurements of tow dynamics. These dynamic measurements could be used to provide mathematical models to tow behavior to augment WES tank test programs which were being planned.

1.2 Test Program Overview

Figure 1 provides an overview of the test program conducted by RMSA in terms of its three principal stages. Stage I was the Pre-Trial Planning stage in which program organization, test

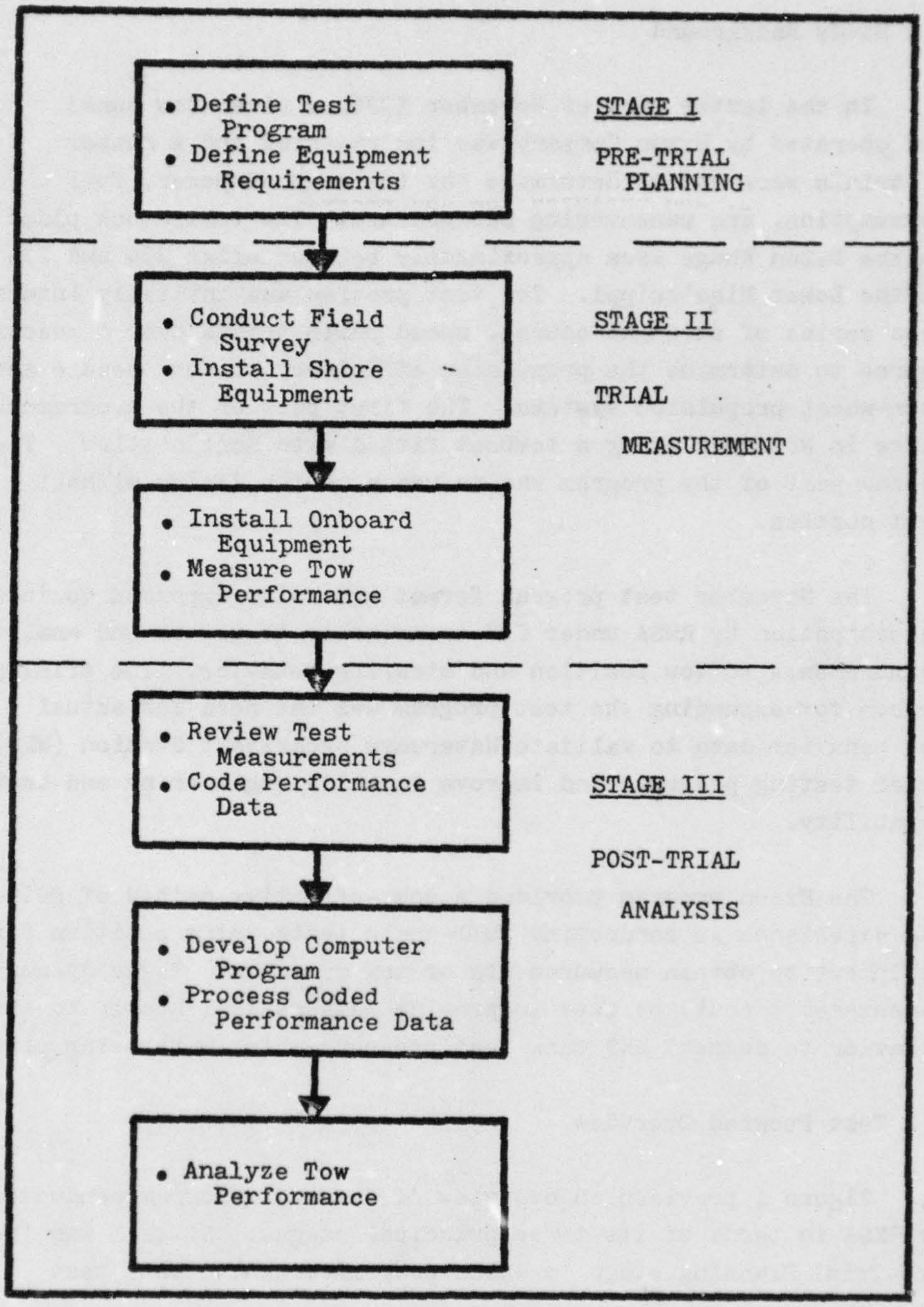


Figure 1. Tow Test Program Overview

instrumentation, and parameter measurement techniques were defined. Stage II was the Trial Measurement stage when field surveys, equipment installation, and tow trial measurements were performed. Stage III was the Post-Trial Analysis stage which coded the test data for the computer, developed computer programs to process the test data, and analyzed tow and program performance.

The Stage I planning established working relationships with the other test participants shown in Table 1. Table 1 gives the individual participants in the November test program, their organization, and their primary test program responsibility. The Exxon staff in Houston was primarily responsible for organizing and coordinating the tow trial activities and had contracted with Dravo Corporation to measure and analyze tow horsepower during the trials. Members from Exxon's staff were to measure fuel consumption during the trials and individuals from the engine manufacturer, Fairbanks-Morse, and the towboat design firm, Hillman Barge & Construction Co., were also expected to participate.

Table 1. Principal Test Participants

Organization	Individuals	Trial Activity
Exxon	M. Bennett	Trial Program Director
	A. Olsen	Fuel Measurement
Dravo	I. Douthwaite	Power Measurement
	C. Dilcher	"
	J. Dagnall	"
Fairbanks-Morse	E. Fazende	Engine Measurement
Hillman Barge & Cons.	E. Shearer	Observer (Towboat Designer)
RMSA	R. Schulz	Steering/Position Measurement
	B. Schulz	"

The trial activities of the participants were reviewed in discussions between WES and RMSA to establish a tentative list of tow performance parameters which would be of most value to future WES programs. This list of parameters, shown in Table 2, was then used to identify trial measurement responsibilities and test instrumentation, equipment, and field survey requirements. Because the data obtained from the trials were to be computerized, the parameters in Table 2 provided a general format for the final data file.

The requirement for geographic measures of tow position indicated a need for shore based equipment and the use of several types of electronic and visual position fixing devices were considered. The Motorola Miniranger system [1] was chosen because it could be readily adapted for use in the test program. Rudder measurements were limited to recording steering rudder angles using a potentiometer connected to the tiller and recording voltage variations.

Table 2. Tow Parameters and Data Collection Responsibilities

Parameter	Measured By:
• Time (Seconds)	RMSA
• Latitude (Tow Center of Gravity)	RMSA
• Longitude (" " " ")	RMSA
• Heading Angle (True)	RMSA
• Distance to Left Bank	RMSA
• " " Right Bank	RMSA
• Depth of Water	EXXON/RMSA
• Current	RMSA
• Propeller RPM	DRAVO
• Horsepower	DRAVO
• Rudder Angle	RMSA
• Speed	DRAVO/RMSA
• Fuel Consumption	EXXON

The Stage II, Trial Measurement activity was centered in Baton Rouge where the trials were held. A field survey was conducted to mark sites for the Miniranger shore equipment and to obtain river current velocity measurements along the trial course. Following the field survey, the Miniranger shore units were placed at the surveyed locations and readied for the trials.

The trials had been established at eight test runs as shown in Table 3. Test equipment was placed on the towboat the day before the trials with final hook-ups and calibration checks performed just prior to the trial runs. The trials, which lasted approximately eight hours, followed the test sequence and data recording schedule given in Table 3. The first four runs were straight course, speed power runs and the last four were steering runs.

Table 3. Tow Trial Survey

Trial Run Sequence	HP	RPM	Fuel	Rudder	Position
	Measurements				
Straight Course Tests					
1. Full Power, Upriver	X	X	X	X	X
2. Full Power, Downriver	X	X	X	X	X
3. 3/4 Power, Upriver	X	X	X	X	X
4. 1/2 Power, Downriver	X	X	X	X	X
Steering Tests					
5. Zig-Zag, Full Power, Upriver	X	X	X	X	X
6. Steady Turn, 1/2 Power, Upriver	X	X		X	X
7. Var. Turn, 1/2 Power, Downriver				X	X
8. Zig-Zag, Full Power, Downriver	X	X	X	X	X

The Stage III, Post-Trial Analysis activities are the subject of this report. Section II describes the physical characteristics of the tow used in the trials. Section III describes the geography of the trial area and the field activities undertaken to support the tow tests. Section IV describes the instrumentation, equipment, and procedures used during the trials. Section V presents the results from the four straight course runs and Section VI the results from the four steering runs. Sections VII through X describe the analysis undertaken to produce a computerized profile of tow dynamics. Sections VII describes the computer analysis required to transform tow position measurements into parametric form to portray tow behavior. Section VIII describes the rudder angle data processing and Section IX the engine measurement data processing. Section X describes the development of the waterway parameters included in the computerized data base. Appendix A gives examples of the computer processing activities described in Sections VII through X and Appendix B contains the engine measurements taken during the trials.

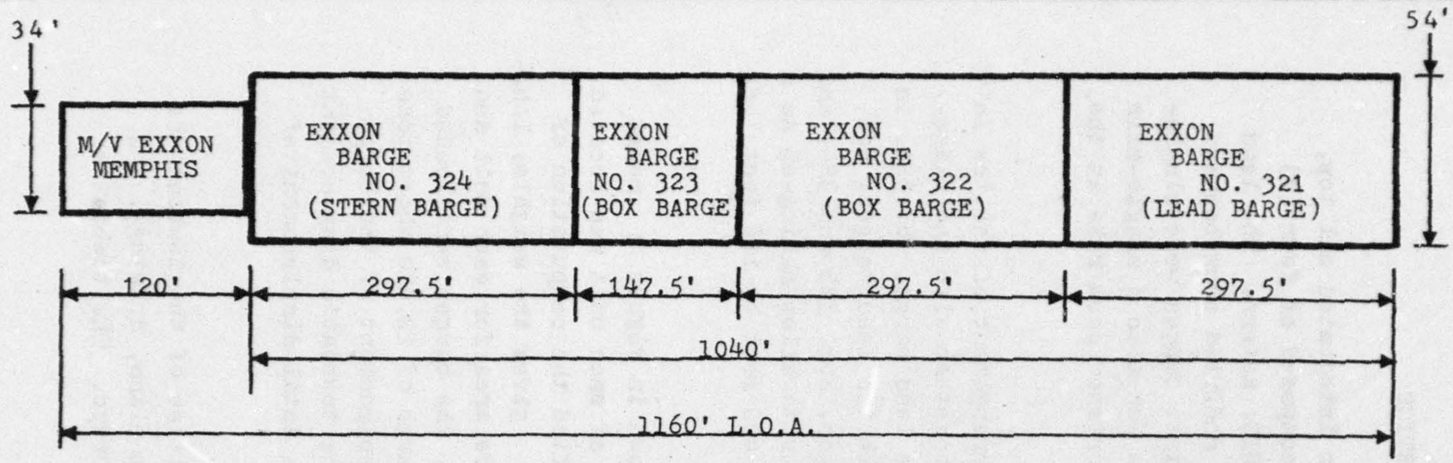
II. TOW CHARACTERISTICS

The tow used for the trial was an integrated oil tow, owned and operated by Exxon Company, composed of four (4) barges with a towboat, the EXXON MEMPHIS, astern. The lead barge was a single-skin design with a modified scow bow and a square stern. The two (2) intermediate barges were single-skin, box designs. The trailing barge was also a single-skin design with square end forward and shortened scow rake at the stern.

Figure 2 shows the plan-view arrangement of the tow in which the tow's dimensions are given together with the placement order of barges and towboat. The lead barge, No. 321, is equipped with a bow-thruster unit. The two lead barges, Nos. 321 and 322, and the two trailing barges, Nos. 323 and 324, and the towboat are sized as separate units to allow making-up as a single tow for single-locking through 600 foot by 110 foot lock chambers.

The single-string arrangement shown in Figure 2 meant that the transverse center of gravity of each unit was located along the tow's centerline and simplified the computation of the tow's center of gravity. Figure 2 gives the weights, longitudinal center of gravity, and surface area for each unit and for the entire tow. During the tests, the barges were loaded to a uniform draft of 9 feet with a cargo of 12,630 short tons of Bunker C. The resulting loaded displacement of the barge string was 15,040 short tons. With the towboat's displacement of 779 short tons added, the tow had a total displacement of 15,819 short tons.

The primary dimensions and capacities of the towboat are shown in Table 4 and were taken from plans, drawings, and documentation furnished by Exxon and Dravo. The towboat's



	Draft, (feet)	LCG, feet (Aft of Bow)	VCB, feet (Above Baseline)	Displacement (Short Tons)	Cargo Weight (Short Tons)	Wetted Surface* (Square Feet)
Barge No. 321	9.0	158.56	4.63	4,150	3,450	20,114
Barge No. 322	9.0	446.25	4.50	4,440	3,750	21,428
Barge No. 323	9.0	668.75	4.50	2,200	1,850	10,628
Barge No. 324	9.0	884.85	4.64	4,250	3,580	20,814
Towboat	8.83	1092.75	4.97	778.72	---	5,665
Tow Total (Average)	(8.99)	(551.38)	(4.59)	15,818.72	12,630	78,649

* Square ends of barges not considered

Figure 2. Tow Arrangement, Weight, and Center of Gravity Data

principal propulsion characteristics are shown in Table 5. The towboat, EXXON MEMPHIS, used in the tests is a moderate size and power towboat fitted with twin screws and Kort nozzles. Shaft horsepower is in the 3300 SHP range developed by 2 Fairbanks-Morse diesel engines. A displacement for the towboat of 779 short tons at an 8'-10" draft was maintained during the trials.

Table 4. EXXON MEMPHIS Dimensions and Capacities

Dimensions	
Length, Overall	120'-0"
" , Design Waterline	117'-0"
Breadth, Molded	34'-0"
Depth, Molded, Main Deck at side	10'-6"
" , " , Top of Headlog	12'-0"
" , " , Top of Sternlog	12'-0"
Draft, Molded, Design Waterline	8'-0"
" , " , Load Waterline	9'-0"
Displacement, Molded, Fresh Water (8'-0")	662.85 S. Tons
" , " , " " (8'-10")	778.72 " "
" , " , " " (9'-0")	783.13 " "
Block Coefficient, Design Draft	0.6678
Tank Capacities	
Fuel Oil, 8'-6" Draft	51,820 Gal.
" " , Max.	76,100 "
Engine Lube Oil	1,015 "
Reduction Gear Lube Oil	290 "
Hydraulic Oil	350 "
Potable Water	6,500 "
Cleaning Fluid	175 "
Air Filter Oil	175 "
Dirty Lube Oil	260 "
Main Engine F.O. Bleed	260 "
Ballast	8,000 "
Slop	4,300 "
Sewage	4,300 "

The EXXON MEMPHIS is powered by 2 10 cylinder, Fairbanks-Morse Roots Blown engines. Each engine is rated at up to 1,667 brake horsepower at 750 RPM with reduction gears providing 216 shaft RPM at that engine speed. The shafts are inboard turning at the top when the engines are moving ahead.

Figure 3 shows the rated performance curves for these engines with shaft horsepower on the vertical axis and engine and shaft RPM on the horizontal axis. The dashed line in Figure 3 shows the average horsepower developed by the port engine during the trials; the dotted line shows the average starboard engine horsepower [2].

Table 5. EXXON MEMPHIS Propulsion Data

Engine System	
2 Fairbanks-Morse, 10 Cylinder Model 10-38D8 1/8, Roots Blown Diesels	
2 Western Reverse Reduction Gears, Model RH27	
Propulsion Characteristics	
Rated Shaft Horsepower	3,334 (1,667/shaft)
Number of Shafts	2
Rated Engine RPM	750
Shaft RPM @ 750 ERPM	216
Rated Towing Speed	10.2 MPH
Gear Ratio, Ahead	3.47
" " , Astern	3.62
Propeller Characteristics (Kort Nozzles)	
Diameter, D	8'-6"
Mean Pitch, P	7'-6"
Pitch Ration, P/D	0.8823
Disc Area	56.745 Sq. Ft.
Hub Diameter	1'-5½"
Number of Blades	4

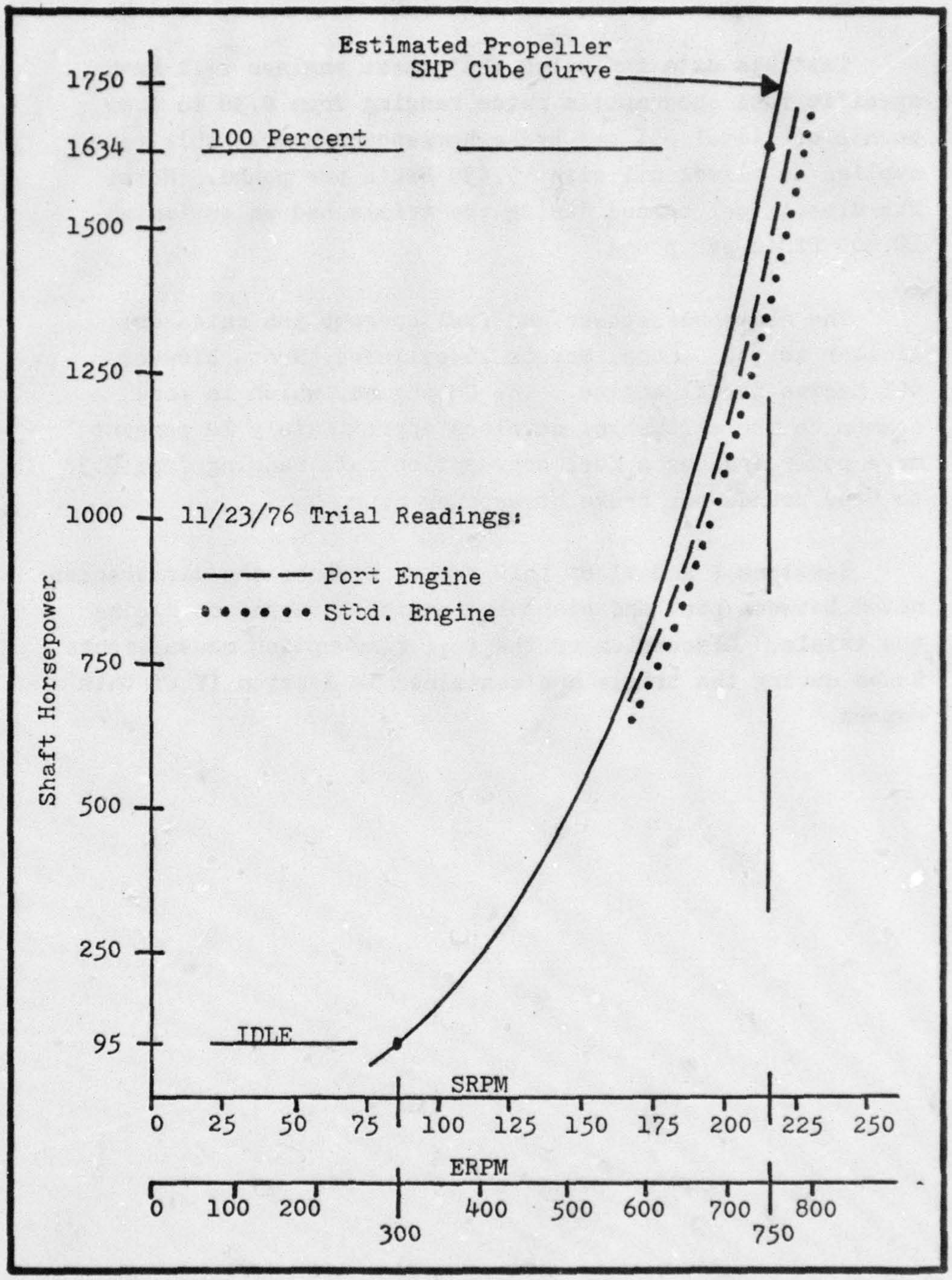


Figure 3. Engine Performance

Test bed data indicates that these engines will have specific fuel consumption rates ranging from 0.36 to 0.40 pounds of diesel oil per brake horsepower hour. This rate applies to diesel oil with 19,630 BTU's per pound. Note: The diesel fuel burned during the trials had an estimated 18,400 BTU's per pound.

The above horsepower and fuel consumption rates are similar to the General Motors 16 cylinder, Roots Blower, 645 Series diesel engine. The GM engine, which is more common on the waterways, develops approximately 10 percent more power and has a fuel consumption rate ranging from 0.38 to 0.40 pounds per brake horsepower hour [3].

Sections V and VI of this report discuss the differences noted between port and starboard engine horsepowers during the trials. Discussion of the fuel consumption measurements taken during the trials are contained in Section IV of this report.

III. TRIAL COURSE FIELD ACTIVITIES

The trial course was established off of Baton Rouge as shown in Figure 4[4]. The primary trial area was a straight, north-south section of the river marked by three ranges located on the western side of the river. The secondary trial area was the river bend north of the 190 Bridge. Figure 4 provides an overview of the trial course geography showing the principal landmarks, shore reference station (transponder) locations for the Miniranger equipment, and trial course range markers. These points are labelled alphabetically in Figure 4 to facilitate the discussions in the text.

The tallest accessible landmark in the area was the State of Louisiana Capitol Building located on the east side of the river (A, Figure 4). Two other landmarks useful in defining the trial area geography were the east and west support towers for the Gulf States Utilities cable crossing (B and C, Figure 4).

The straight-course portion of the trial area, marked at the northern end by the Gulf States Utilities cable crossing towers, extended southward 2.041 miles. Range markers along the west bank marked each end of the course and an intermediate point 0.987 miles below the north range (shown by dashed lines in Figure 4). The trial area extended from river mile 230.8 to 232.8 along a true course of $359^{\circ}56'$ northbound.

The river bend north of the 190 Bridge was the second trial area established to measure the tow's path and behavior when negotiating turns. This area was marked by the placement of two transponders shown as E and F in Figure 4.

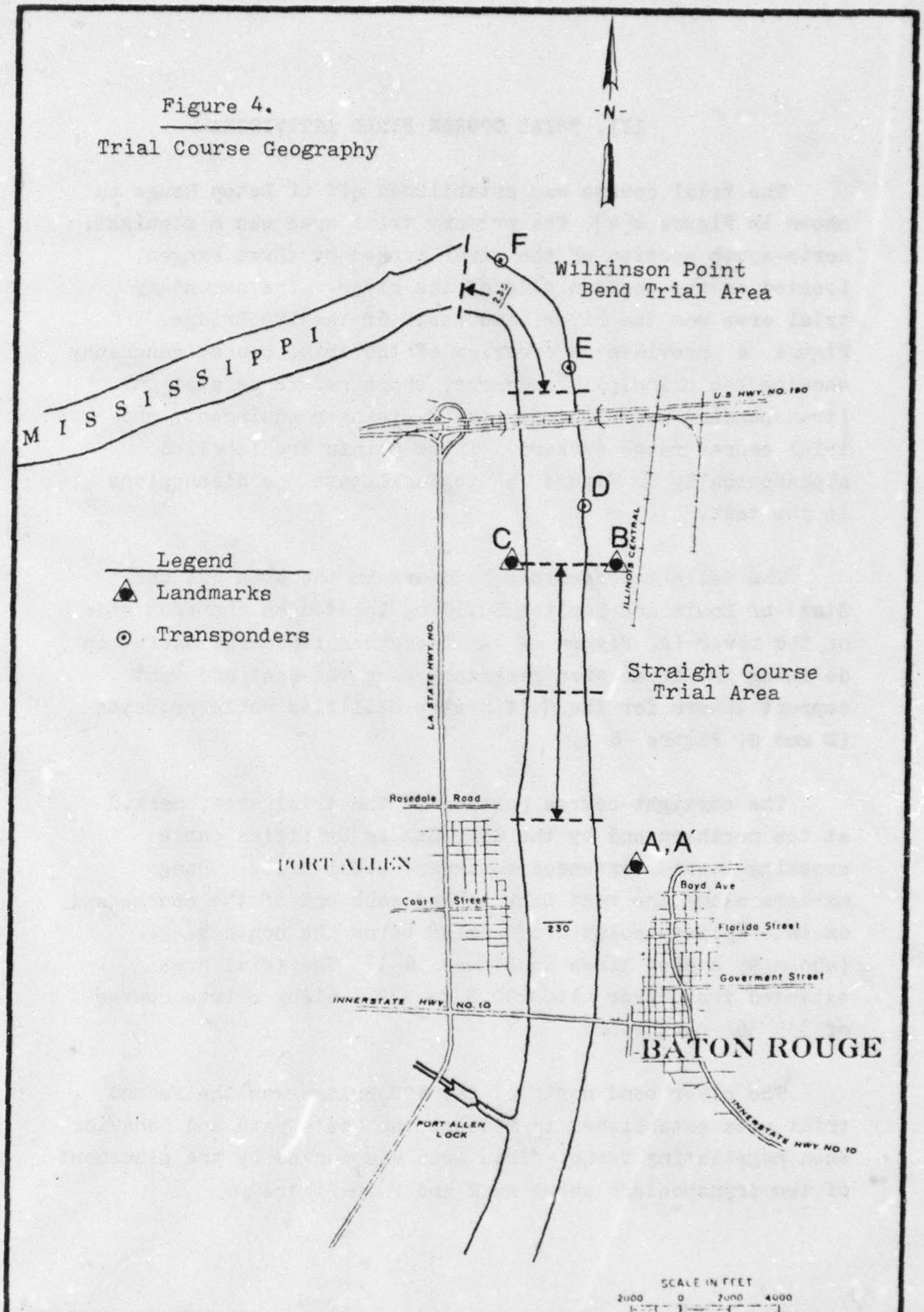


Figure 4.

Trial Course Geography

Both trial areas presented major physical problems. In particular, the lack of high elevations with unobstructed views of the river, the long and relatively narrow test course, and the numerous steel structures such as piers, bridges, towers, and cranes all represented serious constraints to the use of line-of-sight, shore based, distance ranging equipment. In order to meet these constraints, several compromises had to be adopted to ensure that sites chosen for the Miniranger equipment would allow the equipment to function.

The primary factors considered in placing the shore transponders were:

1) Each transponder needed a clear line-of-sight to the antennas on the tow.

2) Two transponder signals (ranges) were required at the tow's antenna to fix its position.

3) The 3 meter accuracy of the Miniranger system indicated that the intersecting angle between signals from two transponders should be greater than 30° and less than 150° (optimally 90°).

4) Each shore transponder needed to be positioned so that the tow's omnidirectional antenna would fall without a 75° horizontal arc.

5) The placement of the four transponders also considered their relative security from theft. Transponder 4 was only accessible by boat while Transponders 1, 2 and 3 were placed on property where 24 hour security arrangements existed.

During the pre-trial survey activity, several photographs of the trial area were taken to assist in evaluating alternative sites for the shore transponders. These photographs,

together with Figure 4 , are used in the following text to describe problems posed by the use of the Miniranger equipment.

Early in the planning it became clear that the placement of the shore transponders would have to consider the waterway segments north and south of the 190 Bridge as two distinct trial areas due to the signal reflecting character of the bridge. Figures 5 , 6 , and 7 were photographs taken of the river segment below the 190 Bridge from the Transponder 1 site on the Capitol Building (A, Figure 4), counter-clockwise from north to south.

Figure 5 shows the northern portion of the straight trial course with Arrow 1 pointing toward the Exxon pier located on the east bank. Arrow 2 points toward the approximate location of the mid-course range markers on the west bank. Arrow 3 shows a tow moving upriver about 500 feet off of the east bank which was continually visible over the entire trial course. During the trials, however, the Exxon pier structure (Arrow 1) apparently reflected signals from the antenna located on the bow of the tow and caused erroneous range readings to be recorded.

Figure 6 is a photograph of the southern half of the trial course showing a clear expanse of river where no signal reflection problems were encountered. Figure 7 shows a one mile segment of the river north of the I-10 Bridge which was used as an approach and turning area during the tow trials. Arrow 1 in Figure 7 shows the dock area where the towboat was tied-up prior to the trials and where the test participants boarded the towboat to install the instrumentation prior to the trials. The ship anchored in the river (Arrow 2) shows the approximate point where the tow was accelerating for the northbound trial runs.

Figure 5.

Northern section of the straight trial course as viewed from the Capitol Building, Transponder 1 site. Arrow 1 is the Exxon pier. Arrow 2 shows a tow moving upriver.

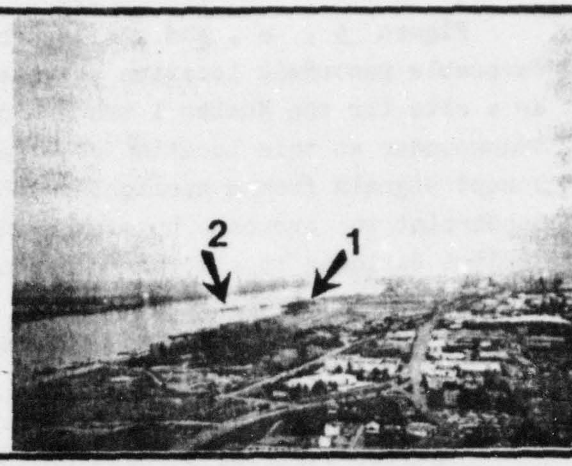


Figure 6.

Southern section of the straight trial course as viewed from the Transponder 1 site.

Figure 7.

River section south of the straight trial course as viewed from the Transponder 1 site. Arrow 1 shows the dock where the towboat was moored prior to the trials. Arrow 2 shows the area where the tow began accelerating for the northbound runs.

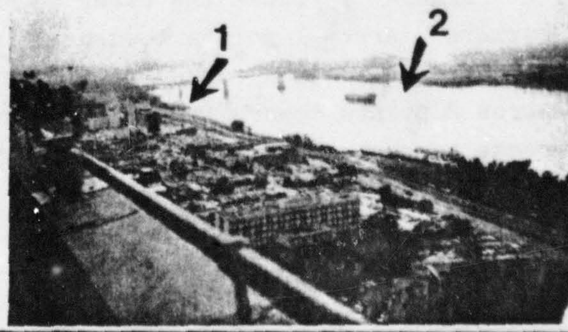


Figure 5 , 6 , and 7 together show the generally favorable panoramic location provided by the Capitol Building as a site for the Number 1 transponder. Placing the Number 1 transponder at this location required that the transponder accept signals from a horizontal arc greater than 75°. This constraint was overcome by stationing an individual on the Capitol Building to aim the transponder during the trials. The on-site manning requirement applied only to the Number 1 transponder. The other transponders were directionally fixed when placed on-site.

A review of geodetic maps of the area, together with the visual survey, indicated that a second transponder should be located along the east bank, close to the water, and north of the cable crossing. Such a site was found on the Allied Chemical property where it was possible to obtain bearings of the three reference landmarks--the Capitol Building and east and west Cable Crossing Towers.

Figures 8 , 9 , and 10 are photographs of the river taken from the Transponder 2 location--counter-clockwise, north to south. Figure 8 shows the river segment between the Number 2 transponder and the 190 Bridge. The middle span of the 190 Bridge (shown by the arrows) was the course later followed by the tow when moving between the straight course and bend trial areas.

Figure 9 shows the river segment around the north range markers. Arrow 1 points toward the west Cable Crossing Tower which was used as a survey reference point (C, in Figure 4); Arrow 2 points toward the approximate location of the north range marker.

Figure 8.

River section between Transponder 2 and 190 Bridge looking northward to the bend as viewed from Transponder 2. The arrows indicate the center span where the tow passed when moving between trial areas.

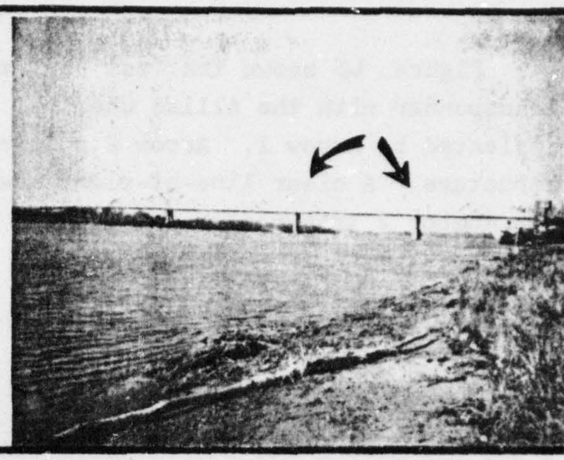


Figure 9.

River section around the north range marker on the west bank as viewed from Transponder 2. Arrow 1 shows the west Cable Crossing Tower. Arrow 2 shows the location of the north range mark.

Figure 10.

Trial course south of Transponder 2 as viewed from Transponder 2. Arrow 1 points toward the Allied Chemical dock. Arrow 2 points to the Exxon pier.

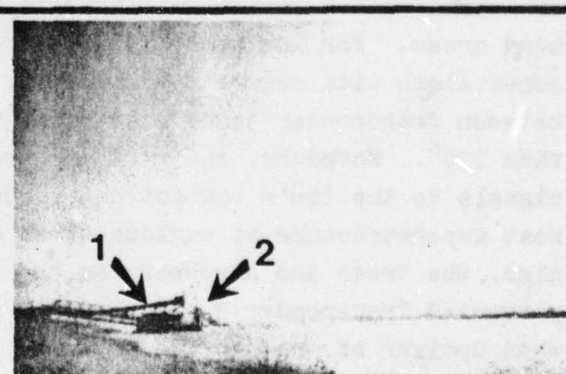


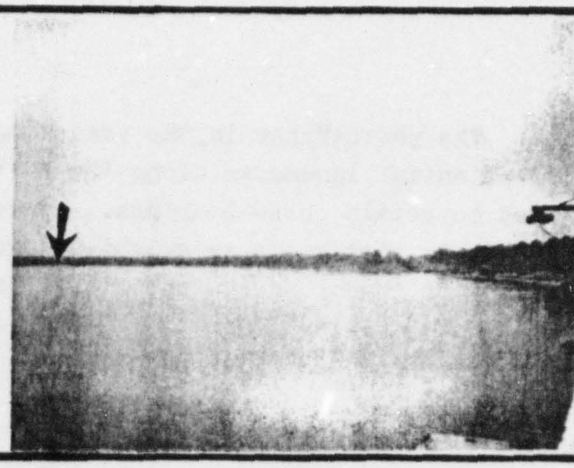
Figure 10 shows the test course south of the Number 2 transponder with the Allied Chemical bulk loading facility indicated by Arrow 1. Arrow 2 points toward the Exxon pier structure. A clear line-of-sight was established between the Number 2 transponder and the tow from I-10 Bridge north to the 190 Bridge.

The trial area north of the 190 Bridge around Wilkinson Point bend posed several problems in determining sites for the transponders. The river banks were overgrown with large trees and shrubs and there were few tall buildings or structures available to serve as elevated locations for the Number 3 and 4 transponders (E and F, Figure 4). Because of this topography, the Stauffer Chemical Dock, located approximately ½ mile north of the 190 Bridge was chosen for the Number 3 transponder (E, Figure 4). The Number 4 transponder (F, Figure 4) was located to provide the greatest area of signal coverage around the bend.

Figures 11 and 12 are photographs taken of the bend area from Transponder 3 on the Stauffer pier. Arrows in each figure point approximately toward Transponder 4 on the north bank. The problems encountered in placing these two transponders are typical of those to be expected in most bend areas. For instance, it was impossible to satisfy the constraints with regard to having the intersecting angle between Transponder 3 and 4 signals greater than 30° and less than 150°. Moreover, the lack of transponder elevation caused signals to the tow's bow antenna to be screened by the towboat superstructure at various times during bend transits. Also, the trees and shrubbery on the inside of the bend prevented Transponder 3 signals from reaching the tow antennas when upriver of the bend.

Figure 11.

Eastern section of the bend area looking north from Transponder 3. The arrow points toward the approximate location of Transponder 4.



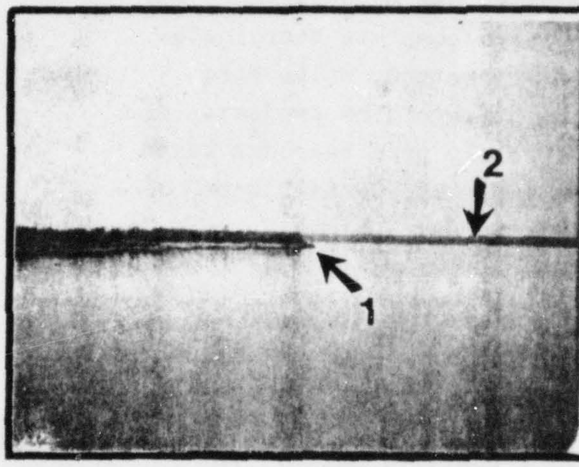


Figure 12.

Wilkinson Point bend area as seen from Transponder 3. Arrow 1 indicates Wilkinson Point. Arrow 2 points toward the Transponder 4 site.

3.1 Transponder Survey Results

The pre-trial survey's major objective was to define geographic coordinates for the shore reference stations (transponders) used to obtain tow position measurements during the trials. Each transponder site was surveyed to obtain triangulation data from which the transponders's geographic position was determined.

The photographs in the preceding text indicate a number of potential landmarks along the river which could have been used to obtain cross-bearings. However, only three of the landmarks with known geographic coordinates were visible from each transponder site. These three landmarks were the State of Louisiana Capitol Building and the east and west towers of the Gulf States Utilities Cable Crossing shown in Table 6.

Field surveys such as this often use both distance and angular measuring devices to derive a complete coordinate mapping of a test area. This survey method, while more accurate, was clearly outside the scope of the project. As a result, the field survy relied solely upon bearings taken of previously surveyed landmarks whose coordinates were tabulated by the National Geodetic Survey [5].

Initially, the test program had intended to develop tow positions based upon the latitude and longitude of the transponders. However, a more appropriate geographic representation for this test program was an X,Y plane coordinate system defining a grid with Y positive north. The National Geodetic Survey publishes tables for each state to convert latitude and longitude data into earth-surface, plane coordinate data in feet [6].

Horizontal bearings of each of the three landmarks were taken from each transponder site. These bearings, together with the known distances between each landmark, provided the necessary survey data to compute the X,Y grid position of each transponder shown in Table 6 using the "three-point resection" technique [7]. Table 6 also shows the distance in feet between each of the survey points.

Table 6. Test Course Reference Points, Coordinates and Distances

Landmark	Latitude (North)	Longitude (West)
A . Capitol Dome	30°-27'-29.294"	90°-11'-14.186"
B . East Power Tower	30°-29'-29.294"	91°-11'-26.867"
C . West Power Tower	30°-29'-29.235"	91°-12'-09.688"

Survey Points	Lambert Plane Coordinates X (Feet)	Y (Feet)
A . Capitol Dome	2046021.62	651035.54
A' . #1 Transponder	2045992.47	651053.21
B . East Power Tower	2044896.07	663617.92
C . West Power Tower	2041149.49	663607.50
D . #2 Transponder	2044145.00	666148.28
E . #3 Transponder	2043521.09	671221.99
F . #4 Transponder	2040900.34	675822.29

Distances

From	To	Feet
A	A'	34.09
	B	12,632.62
	C	13,483.02
	D	15,228.81
	E	20,340.73
	F	25,310.28
A'	D	15,207.70
	E	20,319.63
	F	25,287.09
B	C	3,746.59
	D	2,639.47
	E	7,727.38
	F	12,841.83
C	D	3,927.93
	E	7,975.27
	F	12,217.33
D	E	5,111.93
	F	10,203.64
E	F	5,294.44

3.2 Current Measurements

Current measurements were taken at two locations prior to the tow trials. The first measurements were taken south of the 190 Bridge between the bridge and the north range markers and the second in the Wilkinson Point bend area north of the 190 Bridge.

Orange floats cut from blocks of polyurethane foam (approximately 8" x 18" x 24") were attached to weights at the end of 9 foot lines to act as drags. The length of line was used to make each float respond to both surface and sub-surface currents to approximate current effect on a tow with a 9 foot draft. Each float was uniquely marked so that it could be easily identified from shore.

The first set of current measurements were obtained south of the 190 Bridge using two floats. The floats were dropped south and west of the center bridge pillars and a theodolite, located at the Number 2 transponder site, was used to take bearings as the floats drifted downriver with the time, vertical angle and horizontal angle noted.

At the time the current measurements were taken, a 10-15 mph WNW wind was blowing. It was initially felt that this wind and wave pattern accounted for the eastward drift of the floats. However, a review of Corps of Engineers' furnished charts giving river depth indicated that the natural current path was probably very close to the one portrayed by the track plotted for each float and the wind impact upon current velocity was ignored.

The times and distances when plotted showed that the current averaged 2.9 feet/second for the float to the west and 2.7 feet/second for the float to the east. Because the western-most float should have had a greater velocity, this indicated measurement errors on the order of 0.2 to 0.3 feet/second. An average current of 2.8 feet/second (1.9 mph) was assumed for this segment of the river in later data processing activities.

The second set of current measurments were taken in the channel of Wilkinson Point bend from the Number 4 transponder site. Three floats were dropped upriver of Transponder 4 and sightings of each float were made as they drifted downriver around the bend.

The paths of the three floats were plotted with the northern-most float showing an average current velocity of 2.1 feet/second, the middle float 2.4 feet/second, and the southern-most float 2.1 feet/second. These three current velocities were then averaged and a current velocity of 2.2 feet/second (1.5 mph) was used as the mid-channel current velocity in later processing of the trial data.

IV. TRIAL MEASUREMENTS, INSTRUMENTATION, AND PROCEDURES

The measurements, instruments and procedures for the tow trials are described in this section with primary emphasis on tow position and rudder angle measurements directed by RMSA.

Horsepower and propeller RPM measurements were obtained by Dravo personnel using Maihak torsionmeter equipment [2]. The horsepower measurements were obtained from strain gauges installed on each propeller shaft aft of the reduction gears. These gauges, which provided shaft torque measurements, were calibrated prior to the trials for each shaft at the zero-load point. During the trials, torque readings for each shaft were obtained at about one minute intervals with the revolutions and time of each torque measurement noted. Measurements for each trial run were started and stopped on signal from the pilothouse. These data were compiled and analyzed by Dravo personnel after the trials. This data was furnished to RMSA for inclusion in the computerized data base and was listed in Appendix B.

Fuel consumption measurements were taken by Exxon personnel during the trials by connecting the fuel intake lines of each engine to separate barrels. The fuel in each barrel was weighed at the start and completion of each test run with the weight difference being the fuel consumed by each engine over the measured time interval. The fuel consumed divided by the total power developed by each engine over the time interval gave specific fuel consumption in pounds per brake horsepower-hour. The fuel oil used during the trials had approximately 18,400 BTU's per pound and weighed about 7 pounds per gallon.

4.1 Rudder Angle Measurement

Steering activity was measured by recording only the movement of the steering rudder (flanking rudder movement was not recorded). Because the port and starboard steering rudders were mechanically connected in parallel, it was only necessary to measure the movement of one of the rudders. The rudder measurement arrangement, shown in Figure 13, recorded voltages from a potentiometer connected to the steering system.

A six-foot wire, linear potentiometer was mounted on the hydraulic ram connected to the tiller (A, Figure 13). The wire from the potentiometer was run along the centerline of the hydraulic ram in such a manner as to achieve

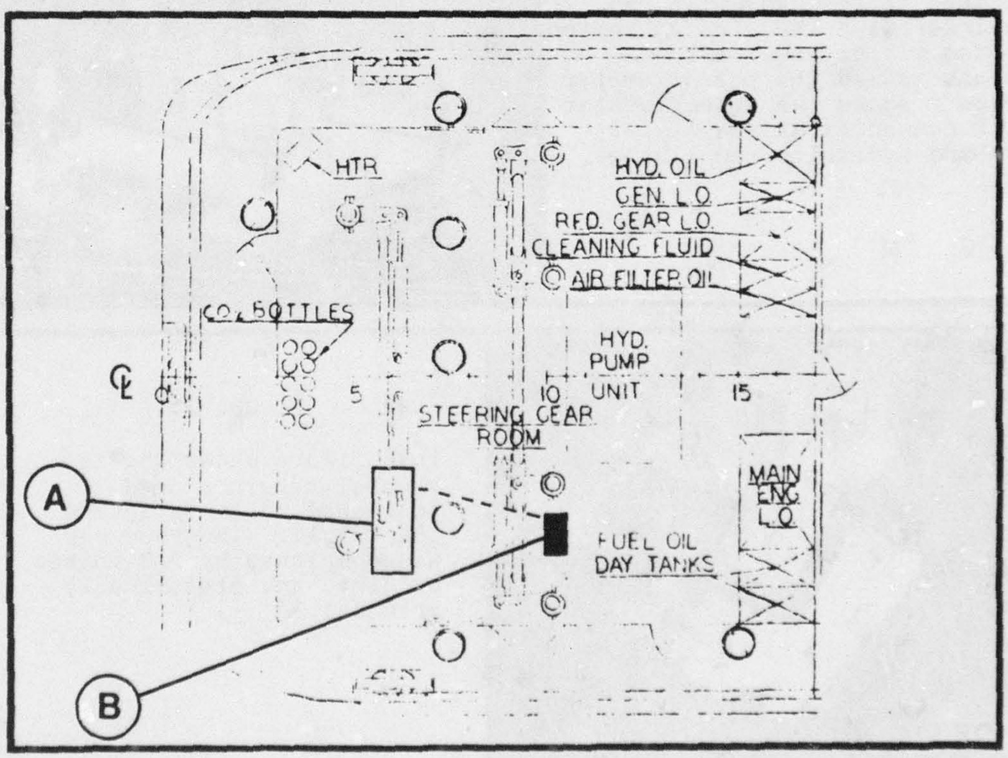


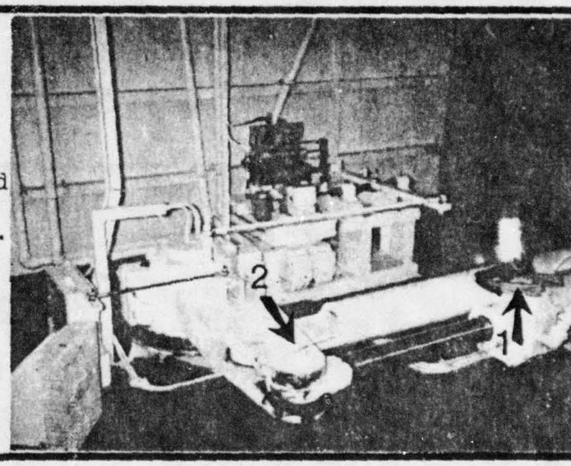
Figure 13. Plan View of Steering Engine Room

a one-to-one linear correspondence between ram extension and wire travel. The voltage source for the potentiometer was a six-volt lantern battery. Output from the potentiometer was fed to a strip-chart recorder which recorded rudder angles as voltage variations (B, Figure 13).

Figure 14 is a photograph showing the potentiometer connected rigidly to the hydraulic ram cylinder with the wire run to the tiller. Figure 15 is a photograph showing the two channel strip-chart recorder used during the trials. The photograph shows the recorder cushioned to reduce deck vibration and grounded to prevent electrical distortion.

Figure 14.

The potentiometer is shown clamped to the hydraulic ram cylinder with the wire connected to the tiller arm. Arrow 1 points toward the potentiometer. Arrow 2 shows the potentiometer wire connected at the tiller arm and hydraulic ram linkage pin.



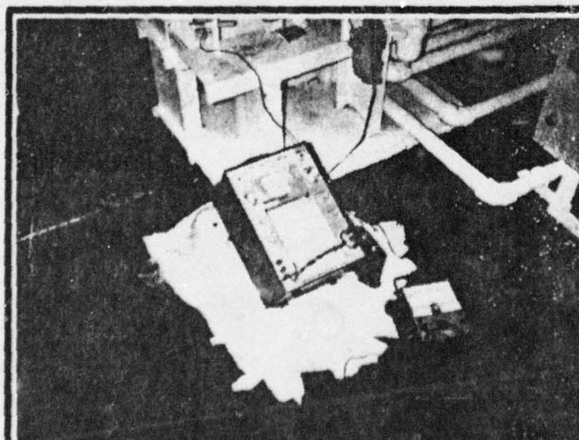


Figure 15.

This figure shows the two channel recorder used to record voltages during the trials. The recorder was cushioned by 2-3 inches of cloth and electrically grounded.

After the recorder and potentiometer were connected, the rudder was swung from amidships to hard over in each direction to calibrate the device. The calibration voltages and rudder angles were later used to develop an equation for translating voltage measurements into rudder angles. This equation is given in Section VIII along with an example of the voltage recording obtained during the trials. It is estimated that the rudder angle measurements obtained during the trials were accurate to $\pm 0.2^{\circ}$.

An interesting problem arose during the rudder angle voltage calibration activity. The pilot had difficulty bringing the rudder into an amidship alignment which indicated that the rudders were probably not amidships underway when the pilot intended them to be. If such were the case, oversteering and reduced linehaul towing efficiency would result.

As a result of the amidship alignment difficulty observed during the steering system calibration, Exxon directed that centerline stops be installed on their towboats. The need for such a device was substantiated after the trials by the relatively frequent occurrence of small port and starboard rudder angles when it was likely that the pilot actually intended the rudder to be amidships.

4.2 Tow Position Measurement

Tow positions along the waterway were recorded by using two Motorola Miniranger II systems [1]. Each Miniranger system provided fixes by measuring the range in meters between two electronic reference stations (transponders) located ashore and an omnidirectional antenna-receiver unit located on the vehicle. The receivers provided updated range measurements at user selectable time intervals with an accuracy of ± 3 meters (one standard deviation) when the signals formed an angle greater than 30° and

less than 150°. A digital printer was attached to the receiver to record time and distances.

Because each antenna-receiver-printer unit recorded its position relative to two known transponder locations, two units on the tow provide simultaneous positions which define the tow's attitude in the waterway. The plan view of the tow shown in Figure 16 gives the separation between the pilothouse antenna (P) and bow antenna (B). This large separation distance reduces the impact of position measurement errors on tow attitude computations. Figure 16 also shows the Miniranger antenna locations in relation to the center of gravity (CG) along the centerline. Both antennas are on the port side of the tow's centerline and are separated by 1,038 feet.

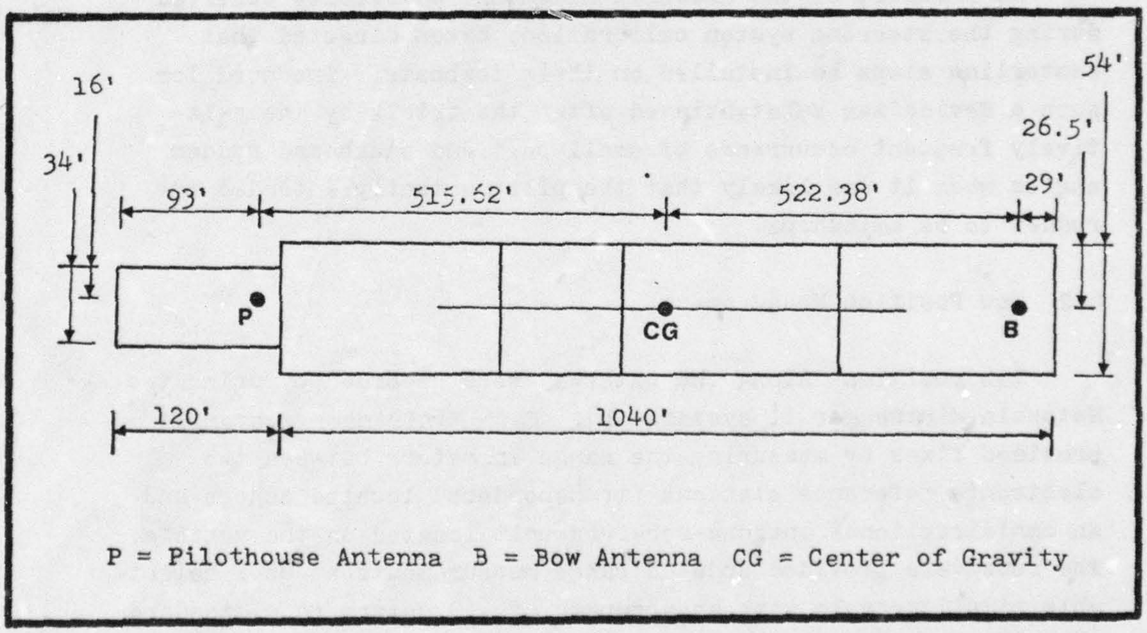


Figure 16. Miniranger Antenna and Center of Gravity Relationships

Figure 17 is a side view of the towboat showing the location of the antenna (A) and receiver units (B). The antenna is shown suspended from a line between radar and light masts and connected to the receiver-printer inside the pilothouse. Locating the antenna in this fashion placed the unit below the radar antenna and relatively clear of adjacent structure.

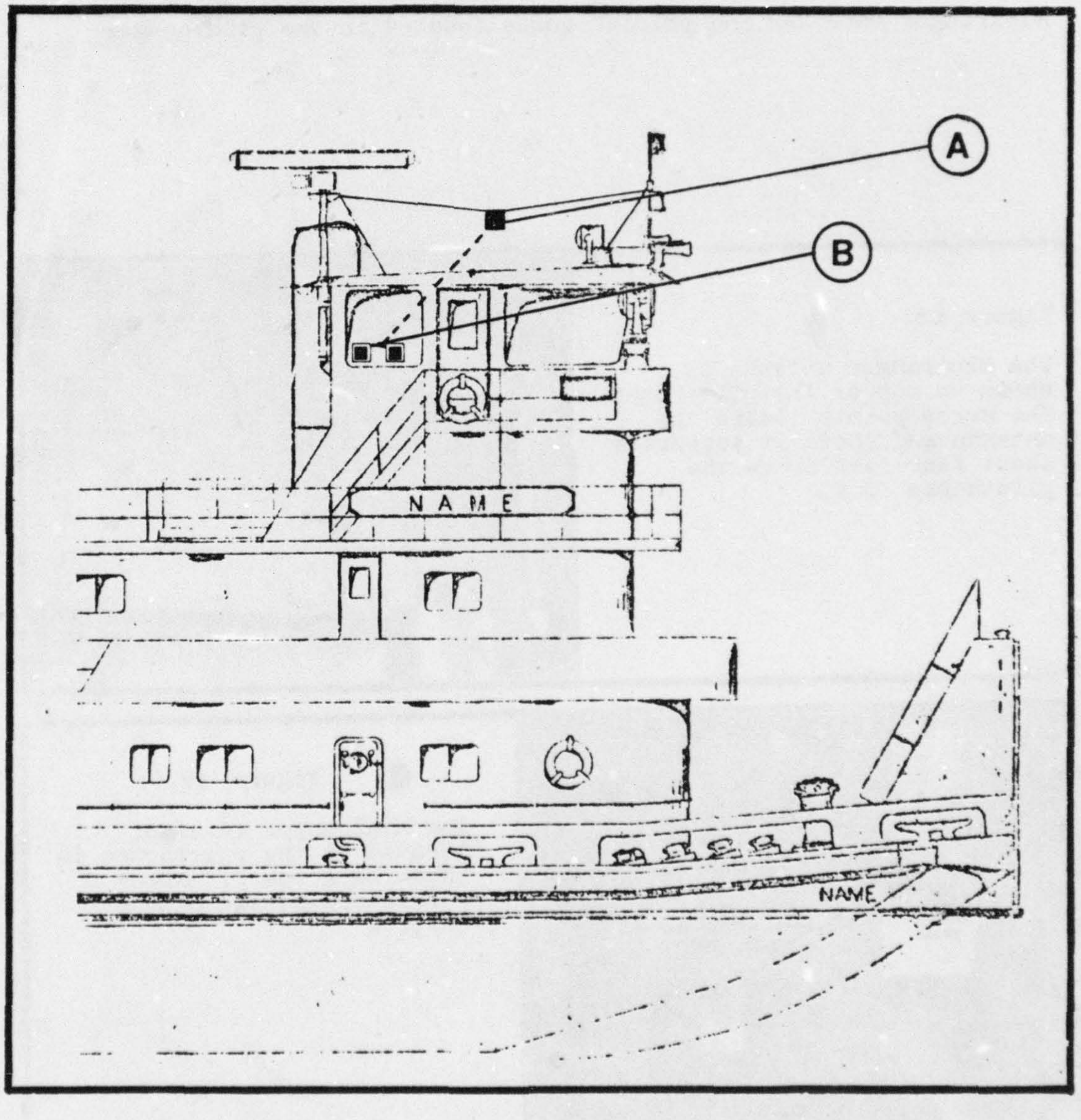
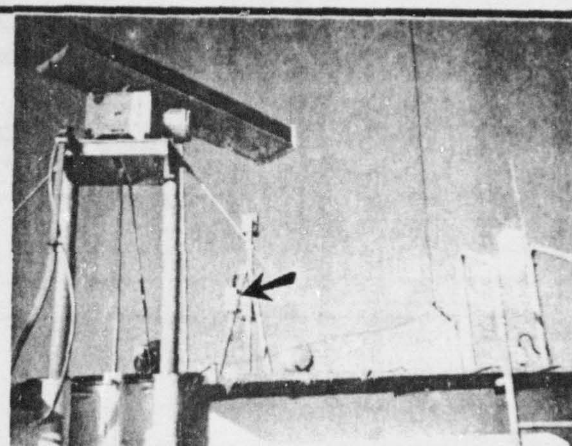


Figure 17. Miniranger Equipment Location on Towboat

Figure 18 is a photograph taken of the Miniranger antenna on top of the pilothouse looking forward on the tow. The arrow in the photograph indicates the antenna location approximately four feet above the deck. Figure 19 is a photograph showing the Miniranger receiver and printer units located in the pilothouse.

Figure 18.

The Miniranger antenna is shown on top of the pilothouse. The arrow points toward the antenna and shows it supported about four feet above the pilothouse roof.



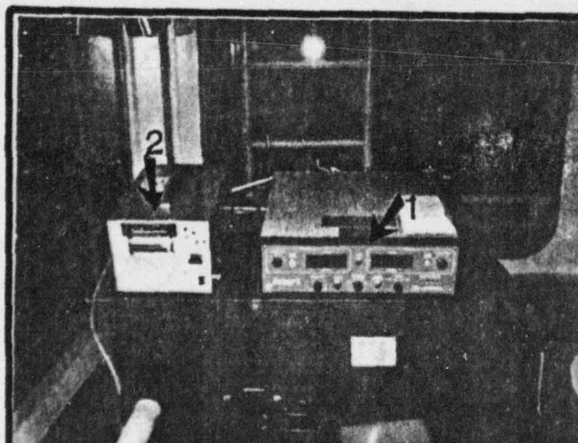


Figure 19.

The Miniranger receiver located in the pilothouse is shown by Arrow 1. Arrow 2 points toward the printer unit.

The Miniranger unit on the lead barge was located as shown in Figure 20. The antenna, shown as A, was located on top of the bow thruster house to be free of surrounding structure. The receiver and printer, shown as B, could not be placed inside and were located on wooden grating aft of an above-deck oil tank to give as much shelter as possible. Because of their exposed position, however, data was recorded less frequently to avoid the possibility of having to replace the paper in the printer unit while underway.

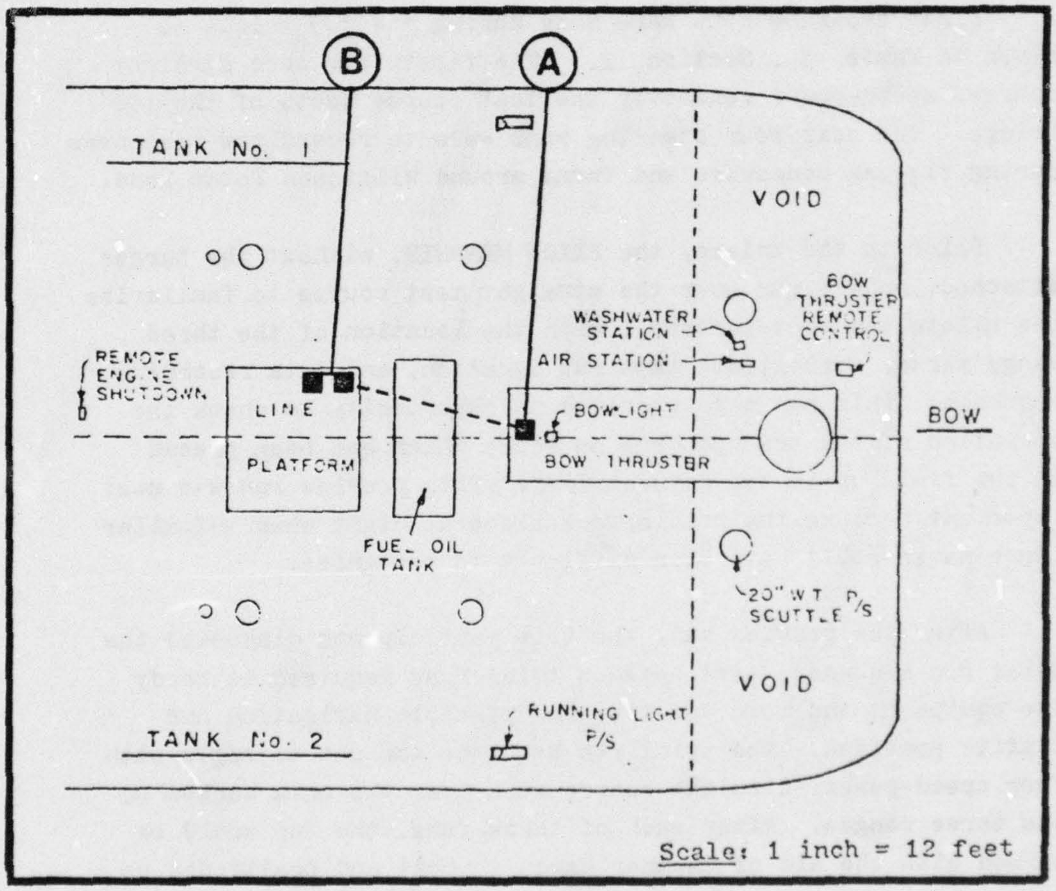


Figure 20. Plan View of Miniranger Equipment on Lead Barge

Tow position measurements were recorded at 1 second intervals by the pilothouse unit and at 2 - 4 second intervals by the bow unit with examples of these data given in Table 17 , Section 7.1. Prior to the trials, the clock in the pilothouse receiver was set to local Baton Rouge time. The time maintained by the pilothouse unit was used as the base time during the trials and the rudder angle recorder and bow Miniranger were both set to the time given by the pilothouse Miniranger unit.

4.3 Trial Procedures

Eight separate runs were made during the tow trials as given in Table 3 , Section I. The first four were straight course, speed-power runs over the test course south of the 190 Bridge. The next four steering runs were to record tow responses during zig-zag maneuvers and turns around Wilkinson Point bend.

Prior to the trials, the EXXON MEMPHIS, without the barges attached, made a run over the straight test course to familarize the pilots and test personnel with the location of the three range marks, approximate test run duration, and data recording sequence. This run also provided an opportunity to check the operation of the transponders on shore which had been placed in the field up to two days earlier. This preview run was most important because the trials took place at night when unfamilar shore marks would have been difficult to recognize.

After the preview run, the test participants discussed the trial run sequence, time between trial runs required to ready the equipment and turn the tow, and possible navigation and traffic problems. The trial run sequence was set to begin with four speed-power, straight course runs over the area marked by the three ranges. After each of these runs, the tow would be turned with the aid of another Exxon towboat and positioned so

that there was ample distance to reach a constant speed during the approach to the first range mark.

Following the fourth (downriver) straight course run, the steering trials would begin with a full-power, zig-zag run upriver with the first rudder deflection occurring when abeam the south range. The tow would then continue upriver for the second steering test, a constant rudder angle turn at half-power around the bend. After the tow was turned the third steering run would be a downriver half-power run negotiating the bend. The tow would continue downriver for the fourth steering run, a full-power, zig-zag test with the first rudder deflection occurring when abeam the north range mark. Each of the four steering runs were made contingent upon having favorable traffic and maneuvering conditions.

Trial activities were directed from the pilothouse by M. Bennett of Exxon who worked with the pilot in coordinating the tow movements for each run and with A. Olson in obtaining fuel measurements. I. Douthwaite of Dravo, stationed in the pilothouse, directed and timed the power and RPM measurements obtained by Mssrs. Dilcher and Dagnall in the engine room. R. Schulz of RMSA, also stationed in the pilothouse, operated the Miniranger and rudder angle recorders on the towboat. B. Schulz of RMSA operated the Miniranger unit on the bow of the tow. The telephone and intercom systems on the tow were used to maintain communication between the pilothouse, engine-room, and bow.

V. STRAIGHT COURSE TRIAL RESULTS

This section describes the first four runs over the straight course shown in Figure 4 , Section III, to obtain speed, power, and fuel consumption data. Run 1 and 2 were conducted at full power, Run 3 at 75 percent power, and Run 4 at 50 percent power, with the time abeam the north, south and mid-course range marks recorded.

Results from each of the four test runs are discussed separately and include observations from the Dravo report [2] as well as summary statistics compiled from the computerized trial data. The computer processing activities are discussed in Sections VII through X with examples of the computerized data base given in Appendix A.

Tow performance for each test run is shown separately for each leg of the test course (including the approach leg) and then combined to show average performance in the tables in this Section.

Figures showing the tow's track are plotted from smoothed position data recorded by the Miniranger equipment with the ranges marking the measured course indicated by dashed lines. The test course segment between the south and mid-course range is referred to as the "south leg"; the segment between the mid-course and north range as the "north leg".

The distance between the north and south ranges was given as 2.041 miles (10776.5 feet). However, Miniranger position measurements obtained when the tow was abeam these ranges indicated that the course length varied depending upon its distance from the west bank. The actual course length was probably 100-150 feet less than 10,776.5 feet indicated.

5.1 Test Run 1 - Full Power, Upriver

Figure 21 shows the tow's path during Run 1 and Table 7 gives its performance over each leg of the course. After the approach leg, the tow had reached a speed of 11.4 mph through the water when it entered the south leg of the test course, 11.9 mph at the start of the north leg, and 11.7 mph at the end of the course. The speed reduction over the north leg was apparently due to the decrease in average water depth from 52.0 to 32.3 feet.

The tow's average speed shown in Table 7 was 11.66 mph through the water over an actual distance of 10,686.7 feet (2.024 miles). The average course followed by the tow was 357.97° true while its average heading was 359.09° due to its 1.12° drift angle. Table 7 shows that the average rudder angle was 2.0° to port due to the fact that the port engine supplied 15 percent more power than the starboard engine over the course.

Both the average rudder and drift angles were greater over the south leg than the north leg. This was surprising since the tow was much closer to the west bank over the north leg which should have caused an increase in drift and an increase port rudder to compensate for the bank and uneven power effects. Table 7 shows that the pilot apparently negated these factors by letting the tow assume a slightly more northerly course.

Drift angle extremes shown in Table 7 were greater in the north leg than the south leg due to the shallower water and proximity of the west bank. Maximum yaw rates of -0.586°/second in the south leg and 0.411°/second in the north leg were observed.

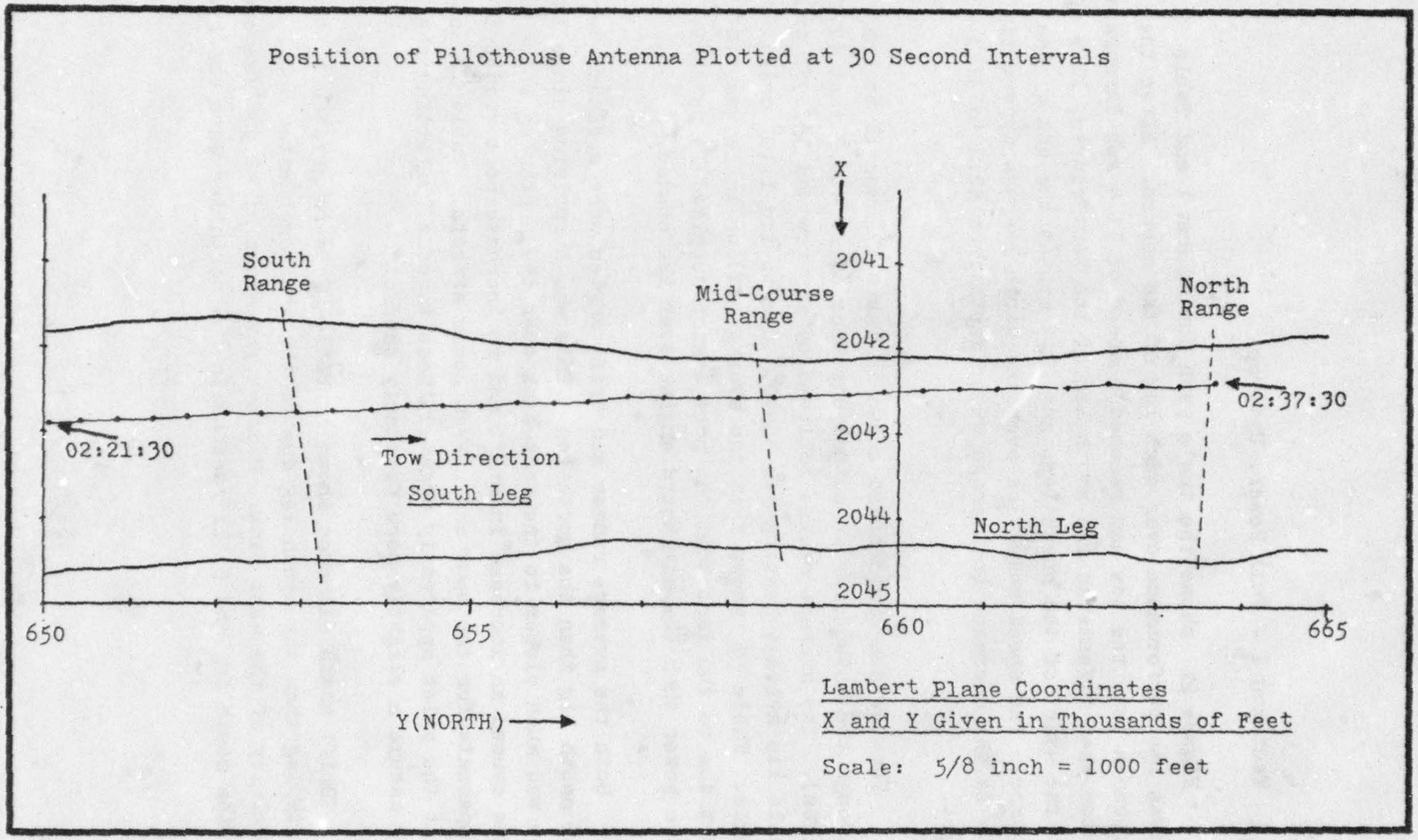


Figure 21. Path of Tow - TEST RUN 1-FULL POWER, UPRIVER

Table 7. Test Run 1 Performance Data
(Full Power, Upriver)

Performance Variable	Approach	Test Course: South Leg	Test Course: North Leg	Test Course: Both Legs	Exxon,* Dravo Data
Time, seconds	348	382	363	745	745.5
Actual Distance, feet	4642.4	5473.8	5212.9	10686.7	10776.5
True Course, degrees	357.46	357.86	358.08	357.97	---
Ave. speed over ground, mph	9.09	9.77	9.79	9.78	9.86
" " " " , fps	13.34	14.33	14.36	14.34	14.47
Ave. speed thru water, mph	11.21	11.63	11.70	11.66	11.61
" " " " , fps	16.21	17.06	17.15	17.10	17.03
Shaft horsepower, stbd.	1514.4	1463.1	1460.0	1461.6	1462.2
" " , port	1752.4	1679.2	1685.1	1682.1	1680.7
" " , both	3266.8	3142.3	3145.1	3143.7	3142.9
Rudder angle, degrees (Positive to port)					
, minimum	-0.8	-3.7	-4.9	-4.9	---
, maximum	5.3	9.0	7.8	9.0	---
, average	2.6	2.2	1.8	2.0	---
Yaw rate, degrees/second (Positive clockwise)					
, minimum	-0.150	-0.586	-0.453	-0.586	---
, maximum	0.152	0.299	0.411	0.411	---
, average	-0.004	0.002	-0.001	0.001	---
Drift angle, degrees (Positive to port of C.L.)					
, minimum	-5.44	-8.25	-11.87	-11.87	---
, maximum	6.90	13.96	16.24	16.24	---
, average	1.10	1.38	0.84	1.12	---
Fuel Consumption rate (Pounds/BHP-hour)	---	---	---	0.359	0.358
Water depth, feet					
, minimum	30.0	39.2	22.6	22.6	---
, maximum	41.8	66.7	51.0	66.7	---
, average	33.6	52.0	32.3	42.4	---

*Data extrapolated from Reference 2 which gave the current effect as 1.75 mph.

5.2 Test Run 2 - Full Power, Downriver

Figure 22 shows the tow's path during Run 2 and Table 8 lists the principal performance data obtained from the run. Run 2 had a relatively short approach and had only reached a speed of 8.7 mph through the water when it entered the north leg of the test course. The tow's speed was 11.2 mph through the water at the mid-course range and 10.8 mph at the end of the run. A maximum speed of 11.9 mph through the water was obtained shortly before the pilothouse was abeam the south range.

The tow had a maximum drift angle of -11.89° a few seconds after entering the north leg of the course and was undoubtedly due to its proximity to the west bank as shown in Figure 22. The average rudder angle over the north leg was -0.1° (approximately amidships) with the effect of the river bank to starboard apparently offsetting the 13 percent greater horsepower delivered to the port propeller.

Table 8 shows that the tow followed a course of 177.01° over the north leg and a more southerly course of 178.98° over the south leg. The lessening influence of the river bank to starboard in the south leg and the 0.9° port rudder angle were not sufficient to compensate for the power imbalance and maintain the tow on the 177.01° course followed in the north leg. If the 177.01° course followed in the north leg had been maintained over the south leg, a more negative drift angle than -1.62° would have resulted.

Table 8 shows that the maximum yaw rates were moderate due to the relatively small rudder deflections used by the pilot with a maximum rudder angle of 7.6° obtained during the test.

Figure 22 shows the tow's deceleration path plotted after passing the south range mark when the engines were reversed and

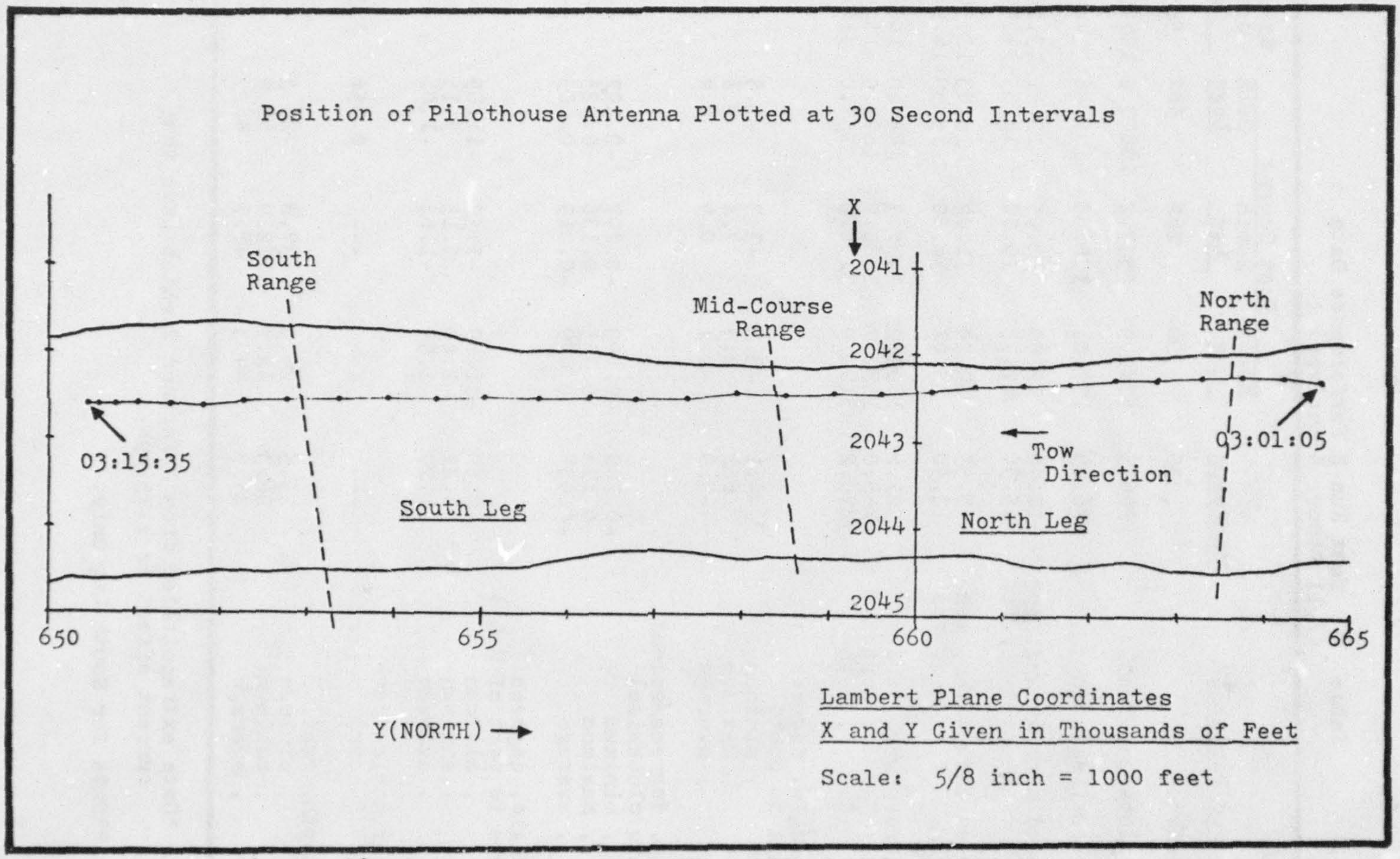


Figure 22. Path of Tow - TEST RUN 2-FULL POWER, DOWNRIVER

Table 8 Test Run 2 Performance Data
(Full Power, Downriver)

Performance Variable	Approach	Test Course North Leg	Test Course South Leg	Test Course Both Legs	Exxon,* Dravo Data
Time, seconds	59	300	282	582	583.0
Actual distance, feet	906.5	5320.0	5357.2	10677.2	10776.5
True Course, degrees	176.03	177.01	178.98	177.96	---
Ave. speed over ground, mph	10.46	12.09	12.95	12.51	13.29**
" " " " , fps	15.36	17.73	19.00	18.35	19.49**
Ave. speed thru water, mph	8.53	10.24	11.04	10.63	11.54**
" " " " , fps	12.50	15.01	16.20	15.59	16.93**
Shaft horsepower, stbd.	1521.2	1492.2	1477.3	1485.0	1486.7
" " , port	1758.0	1682.7	1660.7	1672.0	1675.8
" " , both	3279.2	3174.9	3138.0	3157.0	3162.5
Rudder angle, degrees (Positive to port)					
, minimum	-4.1	-3.3	-3.3	-3.3	---
, maximum	6.1	2.9	7.6	7.6	---
, average	-0.9	-0.1	0.9	0.4	---
Yaw rate, degrees/second (Positive clockwise)					
, minimum	-0.229	-0.193	-0.297	-0.297	---
, maximum	0.114	0.325	0.136	0.325	---
, average	-0.038	0.009	-0.019	0.005	---
Drift angle, degrees (Positive to port of C.L.)					
, minimum	-6.59	-11.89	-7.57	-11.89	---
, maximum	4.21	2.60	5.15	5.15	---
, average	-1.79	-1.99	-1.62	-1.81	---
Fuel consumption rate (Pounds/BHP-hour)	---	---	---	0.356	0.355
Water depth, feet					
, minimum	25.5	26.3	37.8	26.3	---
, maximum	26.3	62.7	62.9	62.9	---
, average	25.7	44.3	48.7	46.4	---

*Data extrapoltated from Reference 2 which gave the current effect as 1.75 mph.

**Data for South Leg only.

the tow slowed at close to its maximum deceleration rate. When the engines were first reversed, the tow had a velocity of 11.1 mph through the water and 13.1 mph over the ground. While stopping, the tow covered a distance of 2550 feet in 227 seconds before its speed was reduced to 1.0 mph through the water and 2.8 mph over the ground. Although the tow's deceleration path was straight, its drift angle went from close to zero when the engines were first reversed to -14.8° at the end of 227 seconds. This large drift angle was almost certainly caused by the port and starboard power imbalance. Perhaps of greatest importance, the data indicate that a tow of this size (1160' x 54') could require a 300 foot wide channel in order to perform a crash stop safely.

While simplifications regarding tow behavior are often misleading, comparing the tow's behavior at full power over the south leg of the course in Runs 1 and 2 offer insight into the effect of the port and starboard power imbalance. In Run 1, the tow's average drift angle was 1.38° and its average rudder angle was 2.2°; in Run 2, the drift angle was -1.62° and rudder angle was 0.9°. Extrapolating this data and excluding upstream and downstream current effects, the 13-15 percent greater power delivered by the port engine developed a turning moment which required 1.6° to control.

5.3 Test Run 3 - 3/4 Power, Upriver

Figure 23 shows the path of the tow during Run 3 and Table 9 lists the Run 3 performance data. After the approach leg, the tow was travelling at 10.48 mph through the water when abeam the south range, 10.52 mph when abeam the mid-course range, and 10.67 mph at the end of the course. Table 9 shows that the tow's average speed was 10.69 mph through the water, its course was 358.51°, and distance travelled was 10696.4 feet (2.023 miles).

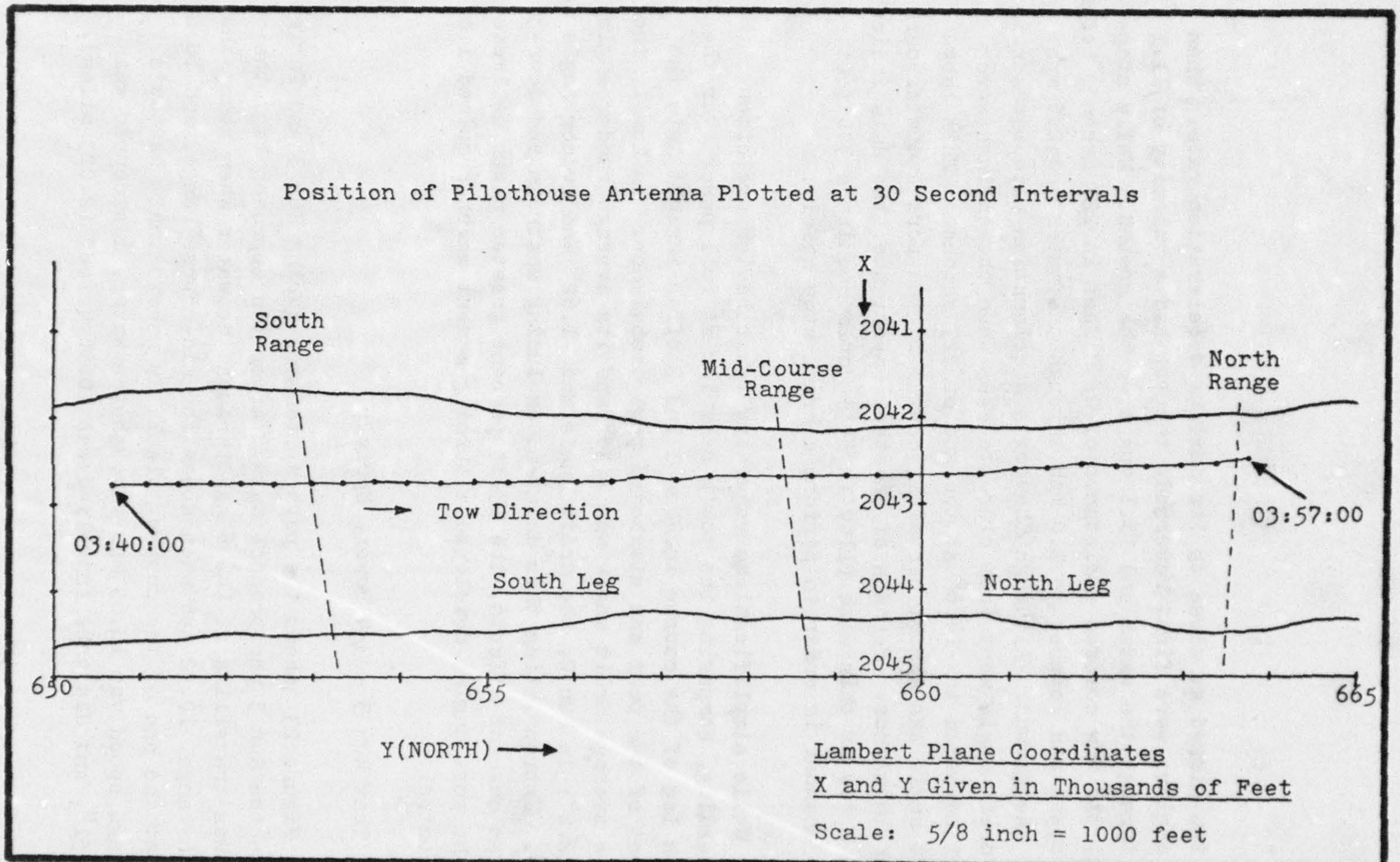


Figure 23. Path of Tow - TEST RUN 3, 3/4 POWER, UPRIVER

Table 9. Test Run 3 Performance Data
(3/4 Power, Upriver)

Performance Variable	Approach	Test Course South Leg	North Leg	Both Legs	Exxon,* Dravo Data
Time, seconds	171	425	403	828	829.0
Actual distance, feet	2137.8	5477.8	5218.6	10696.4	10776.5
True course, degrees	359.53	359.33	357.64	358.51	---
Ave. speed over ground, mph	8.52	8.79	8.83	8.81	8.87
" " " " , fps	12.50	12.89	12.95	12.92	13.01
Ave. speed thru water, mph	10.49	10.66	10.73	10.69	10.62
" " " " , fps	15.38	15.63	15.74	15.68	15.58
Shaft horsepower, stbd.	1068.4	1078.3	1077.1	1077.7	1077.0
" " , port	1193.3	1213.5	1233.9	1223.4	1224.0
" " , both	2261.7	2291.8	2311.0	2301.1	2301.0
Rudder angle, degrees (Positive to port)					
, minimum	-1.2	-2.9	-7.0	-7.0	---
, maximum	5.7	6.1	18.7	18.7	---
, average	1.5	1.5	2.4	1.9	---
Yaw rate, degrees/second (Positive clockwise)					
, minimum	-0.133	-0.452	-0.775	-0.775	---
, maximum	0.103	0.300	0.612	0.612	---
, average	-0.007	0.003	-0.009	-0.003	---
Drift angle, degrees (Positive to port of C.L.)					
, minimum	-4.82	-5.24	-22.18	-22.18	---
, maximum	6.61	13.15	9.96	13.15	---
, average	0.77	1.32	0.80	1.07	---
Fuel consumption rate (Pounds/BHP-hour)	---	---	---	0.358	0.358
Water depth, feet					
, minimum	36.2	35.8	24.0	24.0	---
, maximum	38.0	68.0	45.4	68.0	---
, average	37.5	50.4	31.2	41.1	---

*Data extrapolated from Reference 2 which gave the current effect as 1.75 mph.

Figure 23 shows the tow to be further off the west bank in the north leg than in Runs 1 and 2 which probably accounted for the smaller average drift angle of 1.07° and rudder angle of 1.9°. Maximum drift angles of -22.18° and 13.15° and rudder angles of -7.0° and 18.7° were obtained. The maximum port rudder angle (18.7°) and starboard drift angle (-22.18°) both occurred in the north leg when the turning moment induced by the 13-15 percent greater power supplied by the port engine apparently coupled with the river bank on the port side to produce these extremes.

The maximum yaw rates of -0.775° and 0.612°/second shown in Table 9 were larger than those obtained in Runs 1 and 2. Maximum yaw rates obtained in both of the two upriver tests, Runs 1 and 3, show that yaw rates (negative) were greater to port than to starboard. Run 3 maximum yaw rates were 30-50 percent greater than those obtained in Run 1 when the tow was at full power.

5.4 Test Run 4 - ½ Power, Downriver

Figure 24 shows the tow's path during Run 4 and Table 10 lists the principal performance data obtained from the run. As with Run 2, the approach to the course was too short to allow the tow to reach a constant speed. When the tow entered the north leg it was travelling at 7.6 mph through the water, 8.3 mph when abeam the mid-course mark, and 8.6 mph at the end of the course. Table 10 shows that the tow covered a distance of 10,700.1 feet (2.027 miles) at an average speed of 8.11 mph through the water. The average drift angle over the course was -2.24° with maximum values of -15.13° and 10.46°.

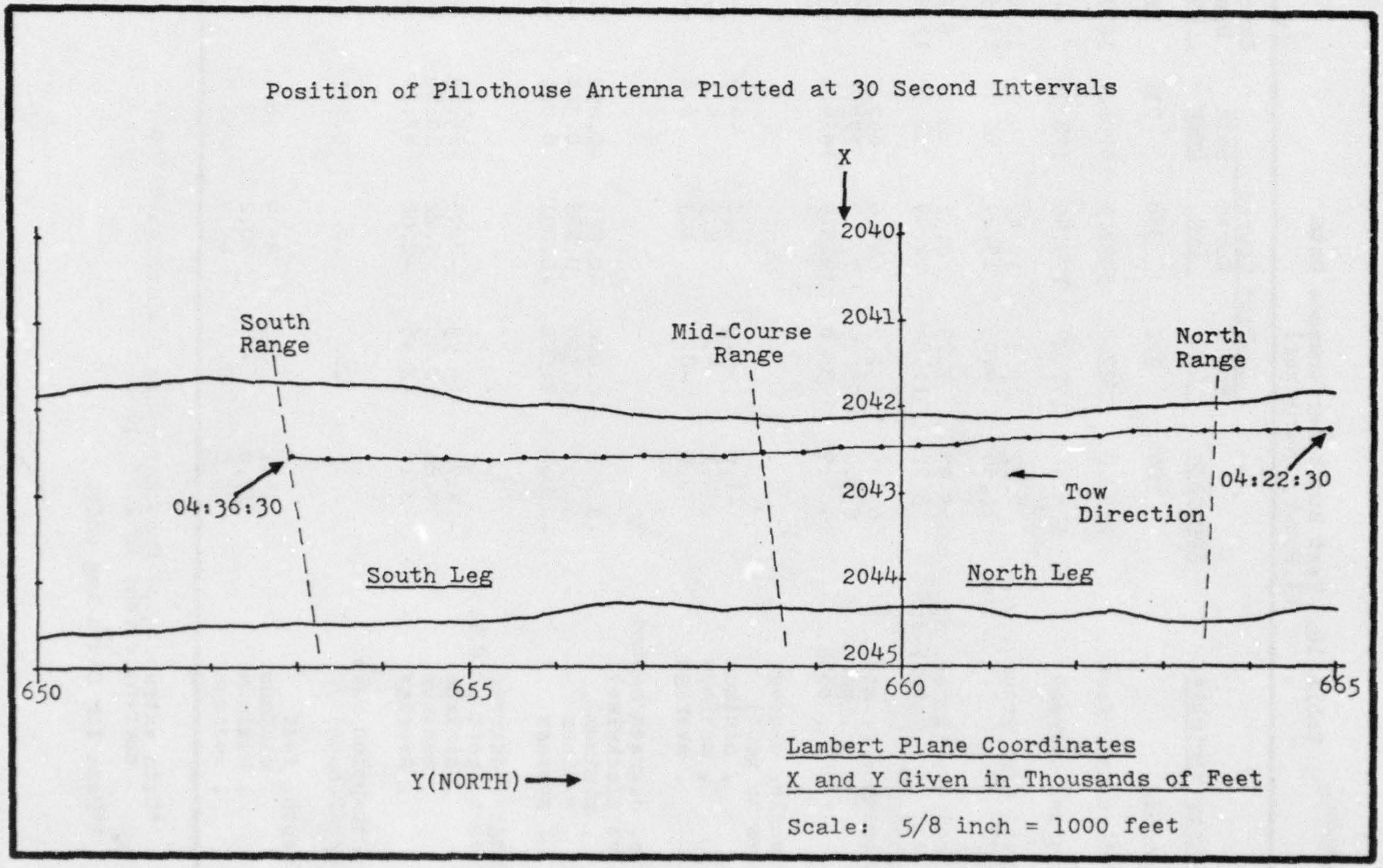


Figure 24. Path of Tow - TEST RUN 4, ½ POWER, DOWNRIVER

Table 10. Test Run 4 Performance Data
($\frac{1}{2}$ Power, Downriver)

Performance Variable	Approach	Test Course South Leg	Test Course North Leg	Test Course Both Legs	Exxon,* Dravo Data
Time, seconds	184	372	358	730	729.5
Actual distance, feet	2122.8	5227.8	5472.3	10700.1	10776.5
True course, degrees	178.40	177.27	179.49	178.36	---
Ave. speed over ground, mph	7.87	9.58	10.42	9.99	10.61**
" " " " , fps	11.54	14.05	15.29	14.66	15.56**
Ave. speed over water, mph	5.93	7.73	8.51	8.11	8.86**
" " " " , fps	8.70	11.34	12.49	11.90	12.99**
Shaft horsepower, stbd.	633.5	652.7	642.6	647.7	652.7
" " , port	830.4	780.9	773.3	777.2	778.1
" " , both	1463.9	1433.6	1415.9	1424.9	1430.8
Rudder angle, degrees (Positive to port)					
, minimum	-1.6	-4.9	0.0	-4.9	---
, maximum	4.1	4.1	2.5	4.1	---
, average	0.8	-0.1	1.3	0.6	---
Yaw rate, degrees/second (Positive clockwise)					
, minimum	-0.200	-0.490	-0.251	-0.490	---
, maximum	0.157	0.504	0.288	0.504	---
, average	-0.008	0.002	-0.001	0.001	---
Drift angle, degrees (Positive to port of C.L.)					
, minimum	-14.72	-15.73	-8.95	-15.73	---
, maximum	9.84	10.46	5.22	10.46	---
, Average	-2.17	-2.46	-2.02	-2.24	---
Fuel consumption rate (Pounds/BHP-hour)	---	---	---	0.371	0.370
Water depth, feet					
, minimum	24.1	26.1	35.9	26.1	---
, maximum	27.4	69.0	70.2	70.2	---
, average	25.0	44.4	45.7	45.0	---

*Data extrapolated from Reference 2 which gave the current effect as 1.75 mph.

**Data for South Leg only.

The tow's path shown in Figure 24 was close to the west bank with a course of 177.27° over the north leg. The -0.1° average rudder angle (amidships) over this leg was apparently due to the force pushing the bow of the tow off the bank being counteracted by the turning moment caused by the 20 percent greater power developed by the port engine. The Run 4 maximum yaw rates of -0.490° and 0.504°/second shown in Table 10 were 55-65 percent greater than those obtained in the full power, downriver run, Run 2.

5.5 Straight Course Trial Conclusions

The preceeding discussion in this section focussed on the trial data typically used to measure tow performance. Of these, the single most important factor appeared to be the greater power supplied by the port engine. This factor undoubtedly caused wider steering fluctuations than might normally be expected and probably reduced tow speed by an amount approximately equal to the added resistance from a constant 1.6° rudder angle.

The steering data in Tables 7 through 10 show that the yaw rate extremes were larger to port on the upriver runs (Runs 1 and 3) while the downriver runs (Runs 2 and 4) had larger starboard yaw rates. Moreover, both of the runs upriver recorded greater maximum yaw rates than either of the downriver runs. The decreased course stability which results at lower horsepower was shown when comparing the extreme yaw rates obtained during the full power and 3/4 power upriver runs and the full power and 1/2 power downriver runs. Run 3 at 3/4 power upriver had extreme yaw rates 30-50 percent greater than test Run 1 conducted at full power. Similarly, Run 4 conducted at 1/2 power downriver had extreme yaw rates 55-65 percent greater than test Run 2 conducted at full power.

One of the difficult problems posed by the velocity data obtained during this study was interpreting variations in tow speed which varied irregularly, both in period and magnitude. A limited analysis of the trial data was conducted which provided little insight into speed periodicity but which provided considerable insight into the magnitude of speed variations to be expected during straight course, constant power runs.

Table 11 lists the average horsepower, speed, and depth data obtained during Runs 1 through 4 over the south leg of the test course with minimum and maximum speed and horsepower values expressed as percentages. The smallest speed variations occurred in Run 2 when the minimum speed was 7.5 percent less, and the maximum speed was 8.2 percent greater, than the average speed. The largest speed variation occurred in Run 4 at 1/2 power when the minimum speed was 18.8 percent less, and the maximum speed 18.2 percent greater, than the average speed. Table 11 shows that speed variations were approximately $\pm$ 8 percent at full power and $\pm$ 18 percent at 1/2 power.

Table 11. Tow Speed Variations Over South Leg

	Run 1 Full Power Upriver	Run 2 Full Power Downriver	Run 3 3/4 Power Upriver	Run 4 ½ Power Downriver
Average shaft horsepower	3142.3	3138.0	2291.8	1415.8
Average speed thru water, mph	11.63	11.04	10.66	8.51
Water depth, feet	52.0	48.7	50.4	45.7
Percentage Speed Variation				
(max.-min)/average	17.4	15.7	18.5	37.0
minimum/average	91.1	92.5	91.8	81.2
maximum/average	108.4	108.2	110.3	118.2
Percentage H.P. Variation				
(max.-min.)/average	2.6	1.0	1.7	5.1
minimum/average	98.9	99.5	99.1	96.0
maximum/average	101.5	100.6	100.8	101.1

Horsepowers varied from 1.0 to 5.1 percent of the average horsepower during a run with smallest variation occurring in Run 2 and the largest variation occurring in Run 4. Because speed varies with the square of horsepower, a 5 percent increase in speed requires a 25 percent increase in power. The relatively large speed and small horsepower variations shown in Table 11 indicate that only a small percentage of the speed variation is attributable to horsepower differences. Steering effects as well as river wave, bank, and bottom effects are primarily responsible for the large speed variations.

VI. STEERING TEST RESULTS

This section discusses the four trial runs (Runs 5-8) conducted to measure steering performance. Runs 5 and 8 were zig-zag runs at full power over the measured course, upriver and downriver respectively. Runs 6 and 7 were upriver and downriver runs at half power around Wilkinson Point bend. Horsepower, rudder angle, and Miniranger position data were obtained for Runs 5, 6, and 8. Only rudder angle and Miniranger position data were collected for Run 7. Figures describing the tow's path were plotted from the computer processed Miniranger position data. Tow performance data are based upon statistics compiled after the computer processing described in Sections VII through X as well as those taken from the Dravo report [2].

6.1 Test Run 5 - Full Power, Zig-Zag, Upriver

Table 12 gives the sequence of rudder movements during the trial Run 5. Figure 25 shows the path and attitude of the tow by separate position plots of the antennas on the pilothouse and bow. Table 13 gives the summary performance statistics for the run and Figure 26 shows the rudder angle, heading change, and drift angle of the tow.

The tow's full power approach to the test course followed a course of 000.42° true and reached maximum speed of 12.09 mph through the water at 05:17:44 when abeam the south range and the first rudder deflection occurred. The pilot moved the rudder right slowly to 10.7° and a constant rudder angle was achieved at 05:18:13. This rudder angle was maintained until 05:19:09 when tow's heading had swung right approximately 10°. The rudder was then moved left to 10.3° which was achieved at 05:19:23. This rudder angle was maintained until 05:21:45 when the tow's head had swung left about 10°. These sequential steering maneuvers

Table 12. Run 5 - Zig-Zag Maneuver Sequence
(Full Power, Upriver)

Maneuver/Event	Time
1. PILOTHOUSE ABEAM SOUTH RANGE	05:17:44
2. Pilot begins starboard rudder movement	05:17:44
3. Rudder angle steady, 10.3° starboard	05:18:13
4. Pilot begins port rudder movement	05:19:09
5. Rudder angle steady, 10.3° port	05:19:23
6. Pilot begins starboard rudder movement	05:21:45
7. Rudder angle steady, 8.6° starboard	05:22:15
8. Pilot begins port rudder movement	05:24:30
9. PILOTHOUSE ABEAM MID-COURSE RANGE	05:24:37
10. Rudder angle steady, 10.3° port	05:25:02
11. Pilot begins starboard rudder movement	05:27:45
12. Rudder angle steady, 9.5° starboard	05:28:19
13. Irregular steering to resume course	05:28:53
14. PILOTHOUSE ABEAM NORTH RANGE	05:31:27

were repeated as shown in Table 12 until the pilothouse was abeam the north range.

Figure 25 shows the paths of the pilothouse and bow antennas over the test course with the points where the paths cross defining the duration of zig-zag maneuvers carried out. Four full zig-zag turns were completed with the fifth cut short so as to bring the tow back to its original course.

The first zig-zag maneuver, when the rudder was placed to starboard, accounted for the largest velocities and accelerations. Approximately 45 seconds after the rudder was deflected to star-

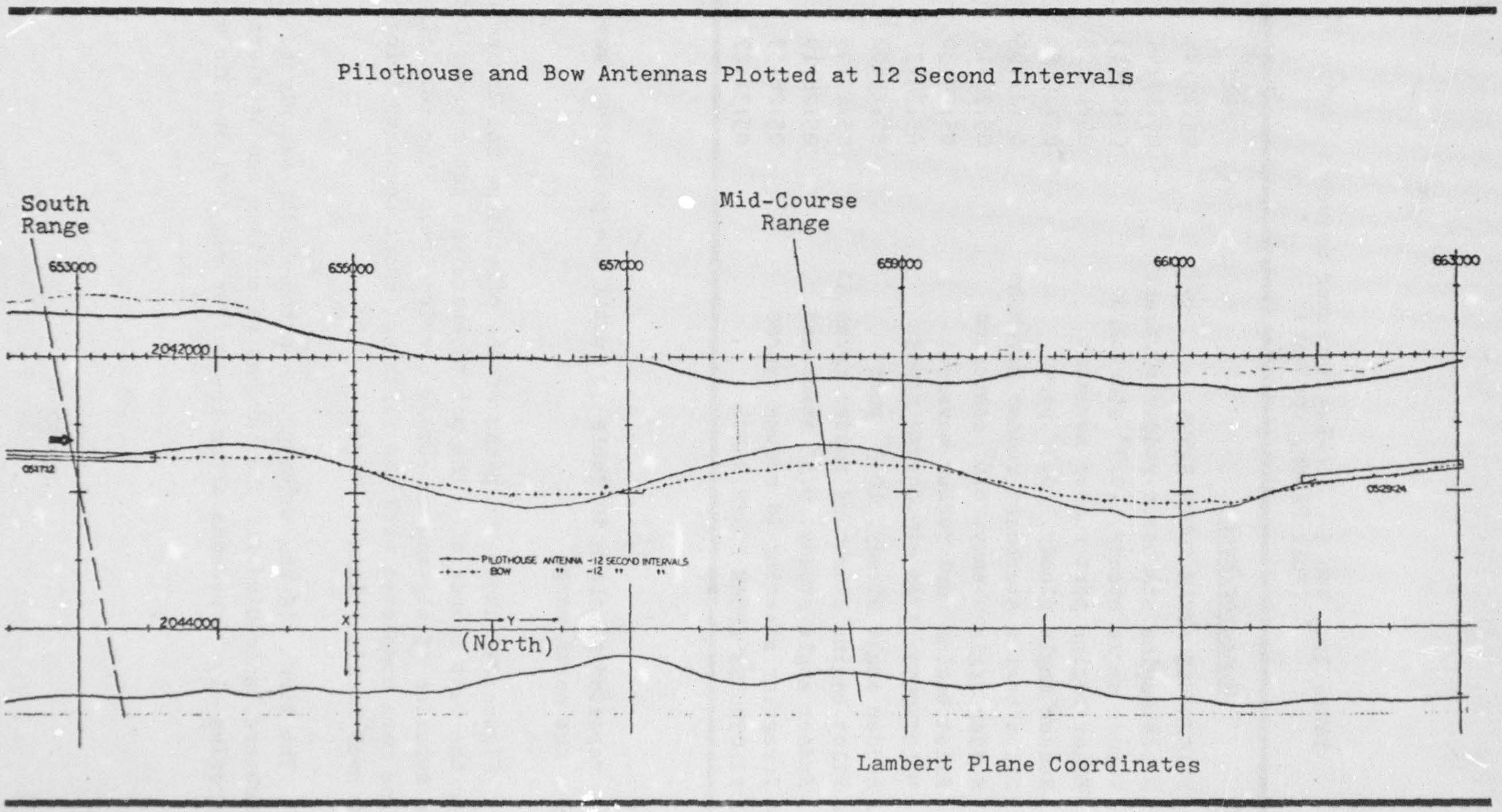


Figure 25. Path of Tow - TEST RUN 5 - FULL POWER, ZIG-ZAG, UPRIVER

board, the tow developed drift angles greater than 20° in each direction with transverse velocities (sway) greater than 4 mph and accelerations greater than 2 feet/second^{2}. Angular velocities (yaw rates) greater than 1°/second and accelerations greater than 0.3°/second^{2} were also noted. These velocities and accelerations were felt by test personnel in the pilothouse during this first maneuver and it was hoped at the time that the Miniranger system would provide range data to establish the magnitude of these tow parameters.

Of particular note, the data developed support the well known phenomenum which occurrs when a constant rudder angle has been applied to a vehicle on a steady course. After the initial rudder deflection, the vehicle moves rapidly (side-slips) in the opposite direction to the intended turn as shown in Figure 25 by the rather sharp curving track of the pilothouse antenna after passing abeam the south range.

Figure 26 shows the heading angle (ψ), rudder angle (δ), and drift angle (β) plotted using the typical zig-zag maneuver format. Large drift angle variations were obtained during the run and were plotted as unsmoothed values to show the periodicity of the data at each stage of the maneuvers.

The zig-zag maneuvers in Figure 26 typically show the increasing amplitudes of heading angle deviation from the initial course with each successive zig-zag maneuver referred to as overshoot. Although Figure 26 provides an indication of tow overshoot during zig-zag maneuvers, the lack of crisp rudder movements and the fact that course changes were based on magnetic compass bearings resulted in a less well defined overshoot profile. However, Figure 26 does show that the starboard rudder maneuvers achieved greater heading angle changes than port rudder maneuvers.

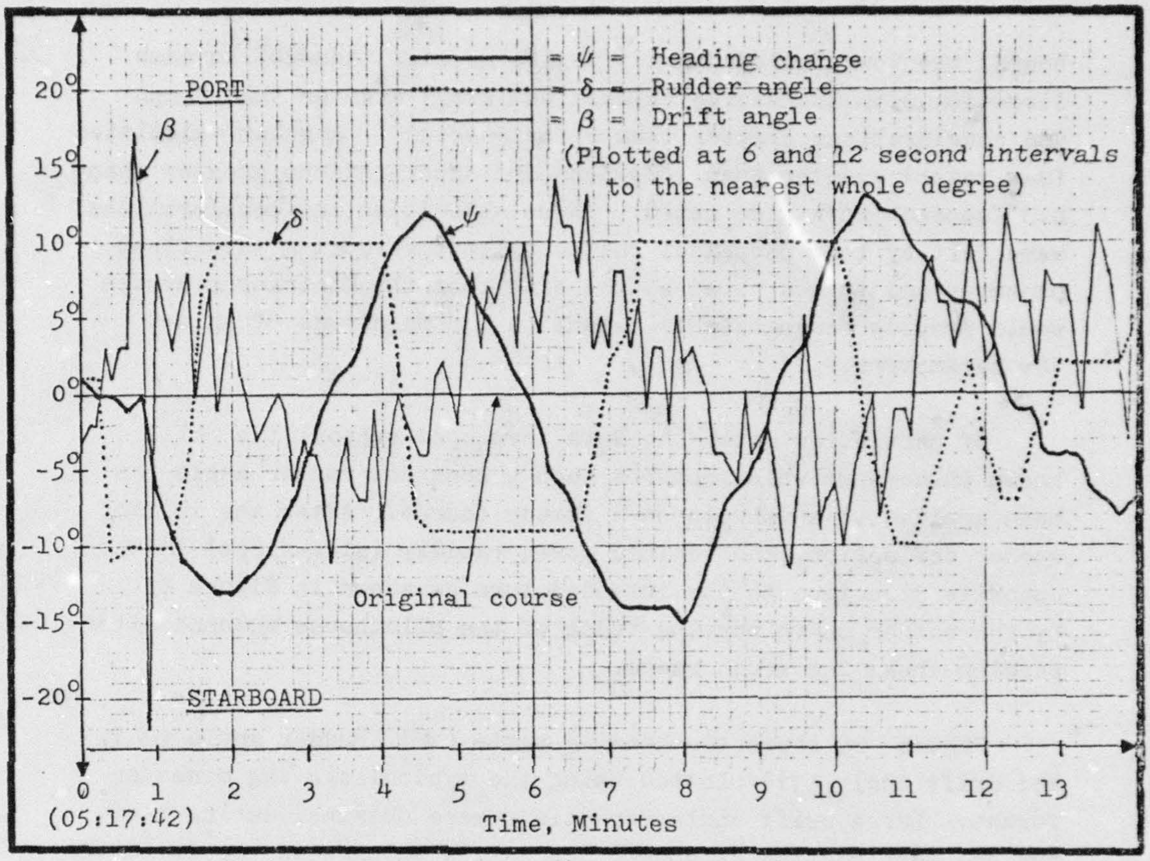


Figure 26. Run 5 - Zig-zag Maneuver Data

This was due to the fact that the 16 percent greater port engine horsepower added to the turning moment of the tow when right rudder was applied.

Speed loss due to these rudder movements was shown in Table 13 by the successively lower tow speeds given for the approach, south and north legs of the course. The tow's average speed over the approach leg was 11.52 mph through the water, 10.93 mph over the south leg, and 10.65 mph over the north leg. For the first three zig-zag maneuvers occurring primarily in the south leg, the

Table 13. Test Run 5 Performance Data
(Full Power, Zig-Zag, Upriver)

Performance Variable	Approach	Test Course South Leg	Test Course North Leg	Test Course Both Legs	Exxon,* Dravo Data
Time, seconds	149	413	410	823	827
Actual distance, feet	2089.5	5498.5	5260.0	10758.5	10776.5
True course, degrees	000.42	000.21	359.70	359.96	---
Ave. speed over ground, mph	9.56	9.08	8.75	8.92	8.90
" " " " , fps	14.02	13.31	12.83	13.07	13.05
Ave. speed thru water, mph	11.52	10.93	10.65	10.79	10.65
" " " " , fps	16.90	16.03	15.62	15.83	15.62
Shaft horsepower, stbd.	1479.9	1489.3	1467.4	1478.4	1492.5
" " , port	1706.4	1700.0	1742.9	1721.4	1708.1
" " , both	3186.3	3189.3	3210.3	3199.8	3200.6
Rudder angle, degrees (Positive to port)					
, minimum	-2.0	-10.7	-9.5	-10.7	---
, maximum	10.7	10.3	10.3	10.3	---
, average	2.3	-1.0	3.0	1.0	---
Yaw rate, degrees/second (Positive clockwise)					
, minimum	-0.153	-0.442	-0.582	-0.582	---
, maximum	0.127	1.051	0.364	1.051	---
, average	-0.013	0.031	-0.011	0.010	---
Drift angle, degrees (Positive to port of C.L.)					
, minimum	-4.01	-21.54	-13.04	-21.54	---
, maximum	3.71	21.46	11.77	21.46	---
, average	0.24	1.55	1.25	1.40	---
Fuel consumption rate (Pounds/BHP-hour)	---	---	---	0.356	0.354
Water depth, feet					
, minimum	34.0	37.7	28.0	28.0	---
, maximum	41.0	62.0	43.0	62.0	---
, average	35.9	46.6	33.9	40.3	---

*Data extrapolated from Reference 2 which gave the current effect as 1.75 mph.

**The straight line distances were shorter for each leg by: Approach, 1.3 feet; South Leg, 66.4 feet; North Leg 72.0 feet; and Both Legs, 138.4 feet.

tow's average speed through the water went from 11.57 mph during the first maneuver, to 10.99 mph during the second maneuver, to 10.56 mph during the third maneuver for a net speed loss of 9 percent. The added loading on the propellers during these three maneuvers generated successively larger horsepowers.

Table 13 shows the performance statistics for the tow over the north and south legs. Because of the sinusoidal path of the tow, the center of gravity traveled 138 feet further along this curved path than along a straight line distance.

6.2 Test Run 6 - Half Power, Steady Turn, Upriver

Test Run 6 was a constant power and constant rudder angle turn around Wilkinson Point primarily to obtain measurements of the tow's drift angle and speed loss. Figure 27 shows the paths of the bow and pilothouse antennas plotted at 12 second intervals during the turn. The turn started at 05:42:11 when the pilot began to move the rudder to port with a constant left rudder angle of 14.9° achieved at 05:42:45. Figure 27 shows the relatively constant drift angle assumed by the tow when moving around the bend. The tow started the turn with a drift angle of -3° which was increased (became more negative) as the tow progressed through the turn. An extreme drift angle of -23.32° was observed 10 seconds after the rudder was steadied at 14.9° to port.

A plot of the tow's performance statistics are given in Figure 28 with the values plotted as 1 minute averages. Figure 28 shows the rudder angle (δ), shaft horsepower (SHP), drift angle (β), velocity through the water (U), and yaw rate ($\dot{\psi}$) for a seven minute period during the turn and clearly demonstrates the interrelationship between these five variables. For instance, shaft horsepower increased in parallel with the rudder angle and indicated the greater power absorption levels of the

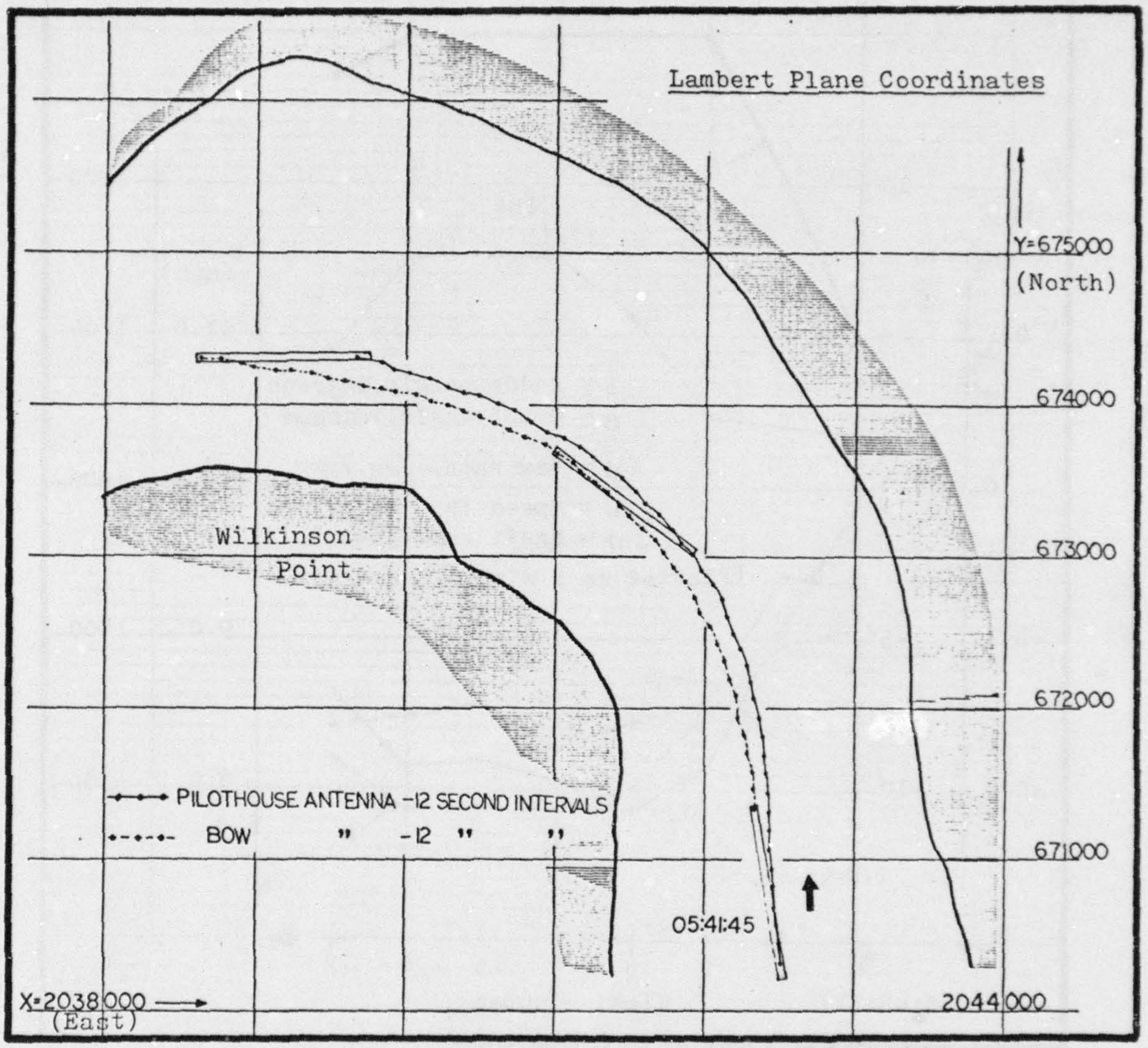


Figure 27. Path of Tow - TEST RUN 6 - ½ POWER STEADY TURN, UPRIVER

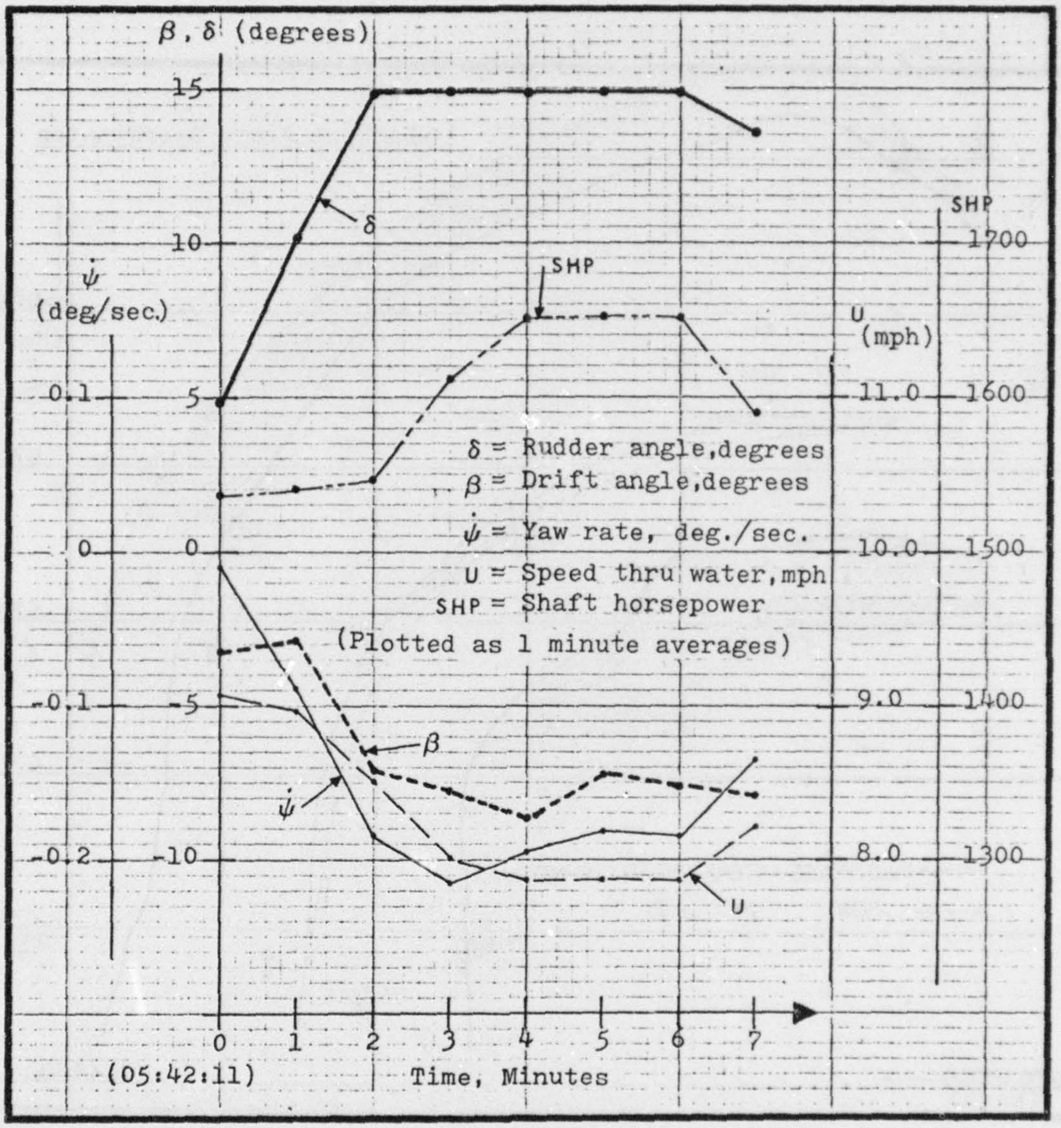


Figure 28. Run 6 - Steady Turn Data (Upriver)

propellers. The interaction between the yaw rate, tow velocity and drift angle are shown by the fact that as the drift angle increased, the tow's angular velocity (yaw rate) also increased. The larger drift angles caused the greater tow hydrodynamic resistance and resulted in a speed reduction. This speed reduction would have been even greater had shaft horsepower remained constant during the turn. As it was, the tow's average speed decreased from 9.07 mph through the water at the start of the turn to an average of 7.86° mph during the 6th minute for a speed loss of over 13 percent.

Indications were that the 13 percent greater power developed by the port engine had less of an impact on tow dynamics during this turn due to the fact that the port propeller was on the inside of the turn. The lesser powered starboard propeller on the outside provided the greater turning moment and resulted in reasonably stable yaw rates and drift angles.

Performance statistics during the upriver turn are given in Table 14 which shows that the tow traveled a distance of 4715.5 feet at an average speed of 8.22 mph through the water to accomplish an 86.9° left turn. For the 480 seconds during the turn, the tow had extreme yaw rates of -0.558° and 0.423°/second with an average yaw rate of -0.162°/second.

6.3 Test Run 7 - Half Power, Turn, Downriver

Figure 29 shows the path oi the tow during the downriver turn around Wilkinson Point bend with the data plotted at 12 second intervals. Although this turn was not a constant rudder angle and constant power turn, no horsepower or fuel consumption measurements were taken during Run 7, engine speed was relatively constant at 590 ERPM.

Table 14. Test Runs 6 and 7 Performance Data
(1/2 Power Turns)

Performance Variable	Run 6* Upriver	Run 7 Downriver
Time, seconds	480	540
Actual distance, feet	4715.5	5586.9
Ave. speed over ground, mph	6.70	7.06
" " " " , fps	9.82	10.36
Ave. speed thru water, mph	8.22	5.50
" " " " , fps	12.06	8.06
Shaft horsepower, stbd.	741.8	651.4
" " , port	835.1	783.1
" " , both	1576.9	1434.5
Rudder angle, degrees (Positive to port)		
, minimum	4.5	-15.8
, maximum	14.9	8.6
, average	13.3	-4.4
Yaw rate, degrees/second (Positive clockwise)		
, minimum	-0.558	-1.343
, maximum	0.423	0.790
, average	-0.162	0.118
Drift angle, degrees (Positive to port of C.L.)		
, minimum	-23.32	-21.42**
, maximum	5.04	62.55**
, average	-7.24	9.97
Water depth, feet		
, minimum	55.8	37.5
, maximum	120.1	142.9
, average	96.2	93.5

*Reference 2 gave Run 6 shaft horsepower as: 733, starboard; 855, port; and 1588, both.

**These extreme drift angles were obtained shortly after the downstream turn began.

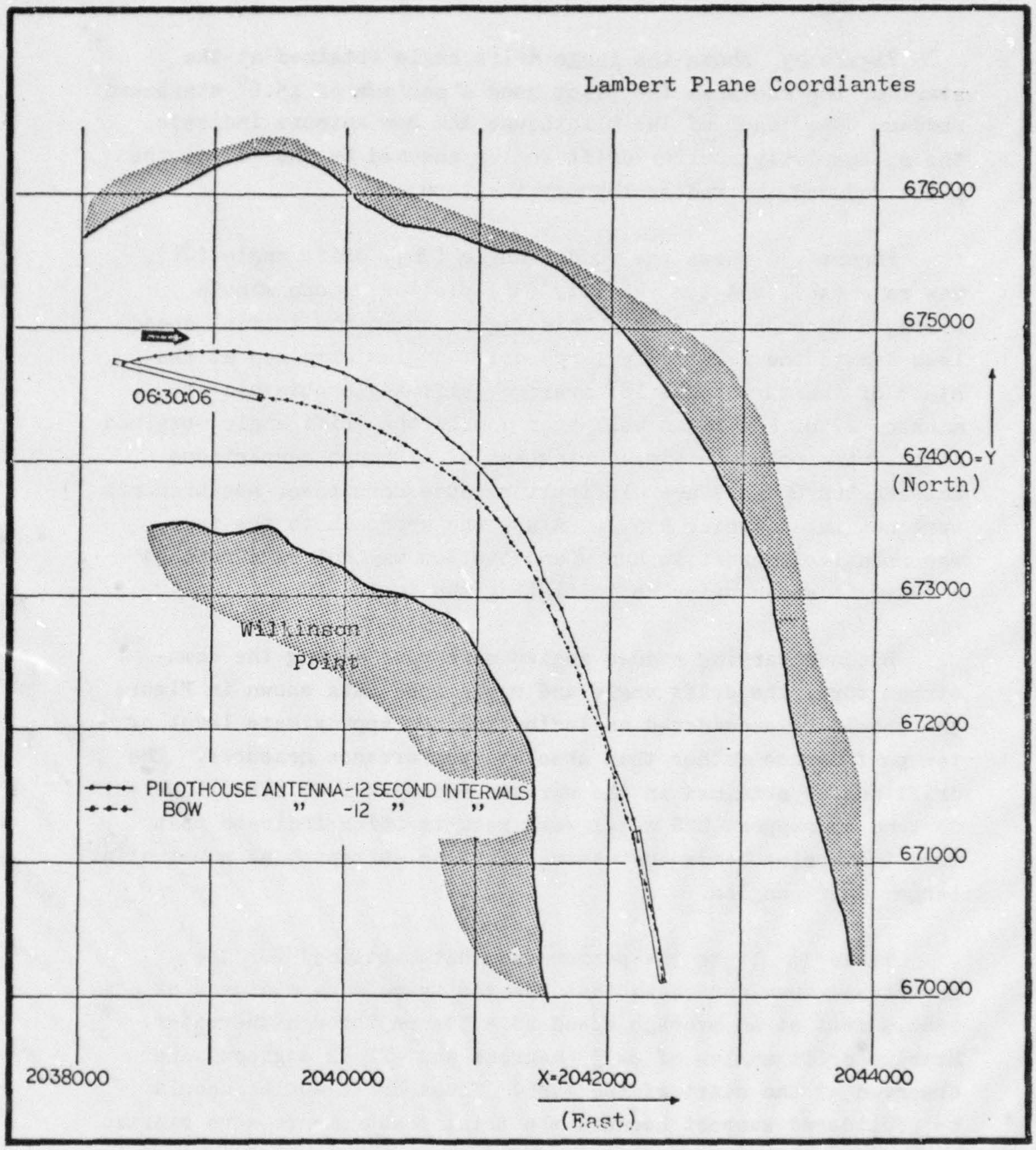


Figure 29. Path of Tow TEST RUN 7 - ½ POWER TURN, DOWNRIVER

Figure 29 shows the large drift angle obtained at the start of the run when the pilot used a maximum of 15.8° starboard rudder. The track of the pilothouse and bow antenna indicate the successively smaller drift angles assumed by the tow as the pilot reduced the rudder through the turn.

Figure 30 shows the rudder angle (δ), drift angle (β), yaw rate ($\dot{\psi}$), and tow velocity (U) plotted as one minute averages through the turn. This figure shows the initial speed loss due to the relatively large drift angles attained at the start of the turn. The 18° average drift angle obtained at minute 2 of Run 7 was well over double the drift angle obtained at the same point in time during Run 6, although comparisons between Run 6 and 7 are difficult because horsepower measurements were not taken during Run 7. Also, the approach to the turn was relatively short in Run 7 and the tow may not have reached a constant speed prior to initiating the turn.

Because varying rudder angles were used during the downstream turn, the drift angle and speed loss data shown in Figure 30 should be considered as indicating the approximate level of tow performance rather than absolute performance measures. The drift angles obtained in the upriver and downriver runs, however, do tend to support WES model test results which indicate that tows traversing bends and moving with the current have substantially larger drift angles.

Table 14 lists the performance data obtained for the downstream turn and shows that the tow traveled a distance of 5586.9 feet at an average speed of 5.50 mph through the water. Extreme drift angles of 62.55 degrees and -21.42 degrees were observed at the start of the turn. These drift angles should be considered suspect because the trial measurements were started about this time and the data could contain both measurement errors

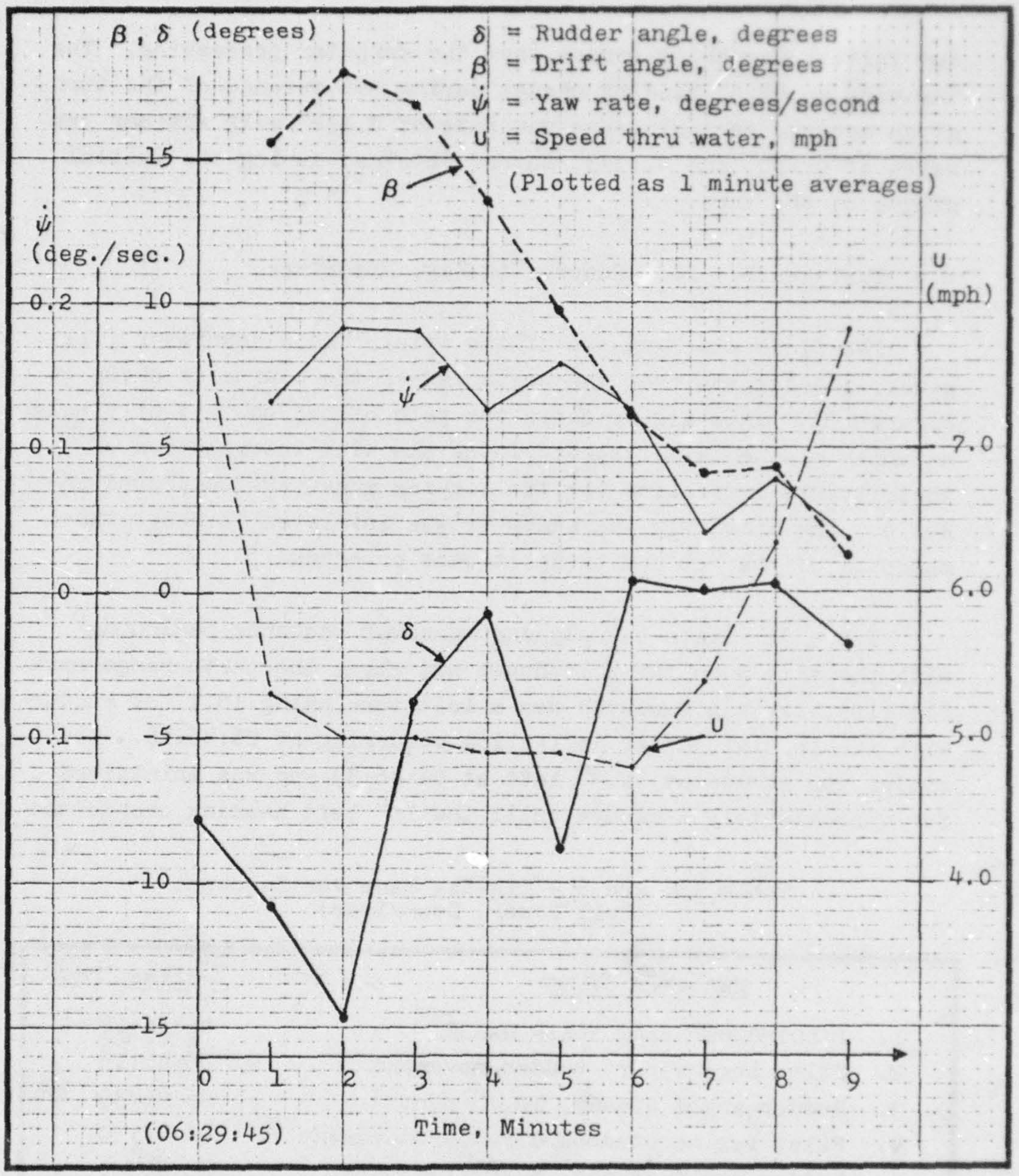


Figure 30. Run 7 - Steady Turn Data (Downriver)

and initial smoothing errors from the computer processing. The tow made an 88.5° heading change during 540 seconds of the turn at an average instantaneous yaw rate of 0.118° with extreme yaw rates of 0.790° and -1.343°/second obtained during the initial stages of the turn.

6.4 Test Run 8 - Full Power, Zig-Zag, Downriver

The final steering run of the trials was a downriver full power, zig-zag run over the north leg of the course as shown in Figure 31. This figure shows the path of the bow and pilothouse antennas plotted at 12 second intervals with intersection of their tracks indicating the two zig-zag maneuvers completed in Run 8. The third zig-zag maneuver was initiated to check the momentum of the tow and bring it back on course.

Table 15 lists the zig-zag maneuver sequence beginning with the time when the pilothouse was abeam the north range mark. The first zig-zag maneuver was a left turn using 10.7° of rudder with the initial rudder deflection occurring at 06:46:18. The rudder was steady at 10.7° left at 06:46:33 and was maintained for approximately 1 minute until the 10° left heading change had

Table 15. Run 8 - Zig-Zag Maneuver Sequence
(Full Power, Downriver)

	Maneuver/Event	Time
1.	PILOTHOUSE ABEAM NORTH RANGE	06:46:18
2.	Pilot begins port rudder movement	06:46:18
3.	Rudder angle steady, 10.7° port	06:46:33
4.	Pilot begins starboard rudder movement	06:47:30
5.	Rudder angle steady, 8.2° starboard	06:47:50
6.	Pilot begins port rudder movement	06:49:57
7.	Rudder angle steady, 9.9° port	06:50:12
8.	PILOTHOUSE ABEAM MID-COURSE RANGE	06:51:13

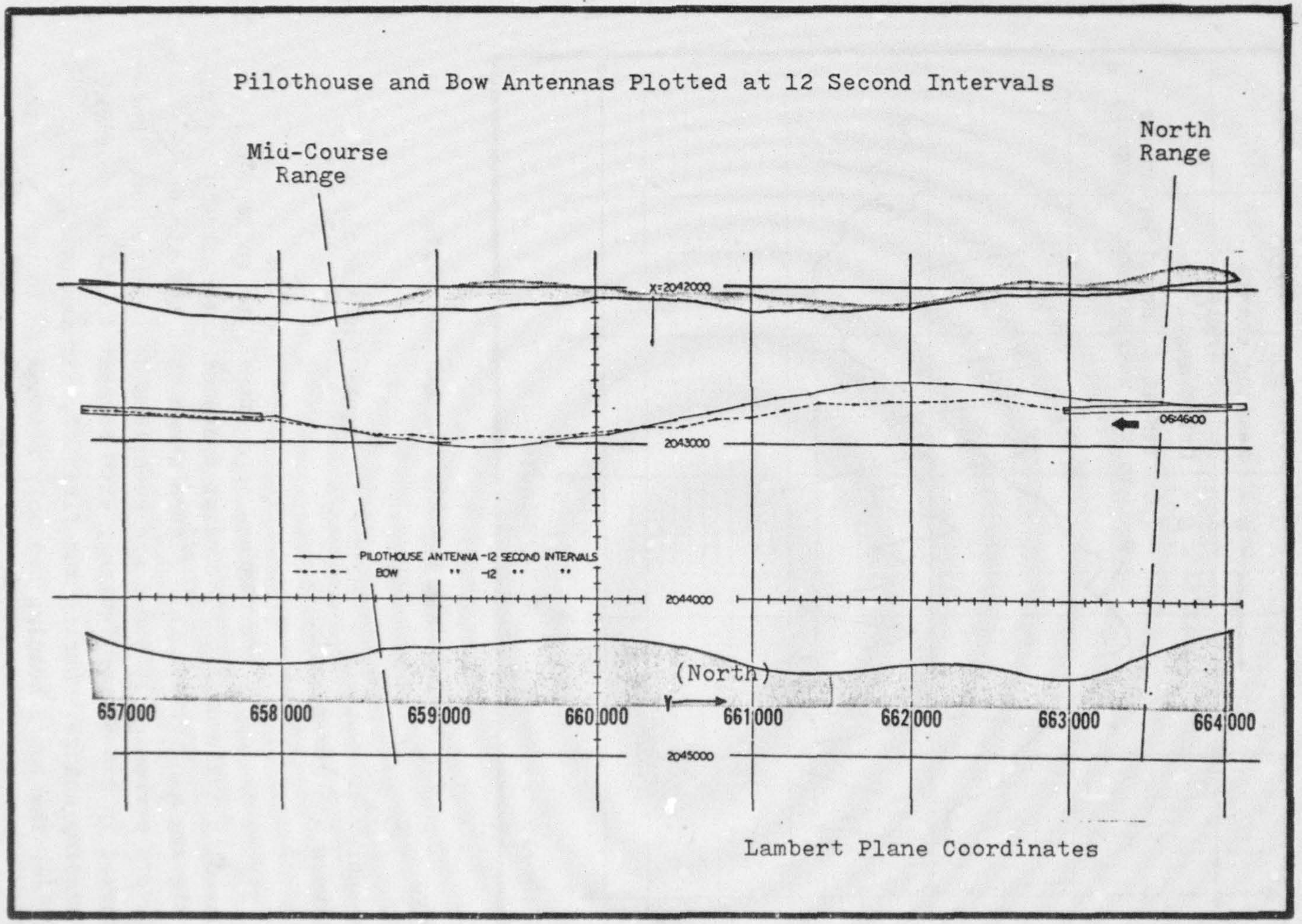


Figure 31. Path of Tow - TEST RUN 8 - FULL POWER, ZIG-ZAG, DOWNRIVER

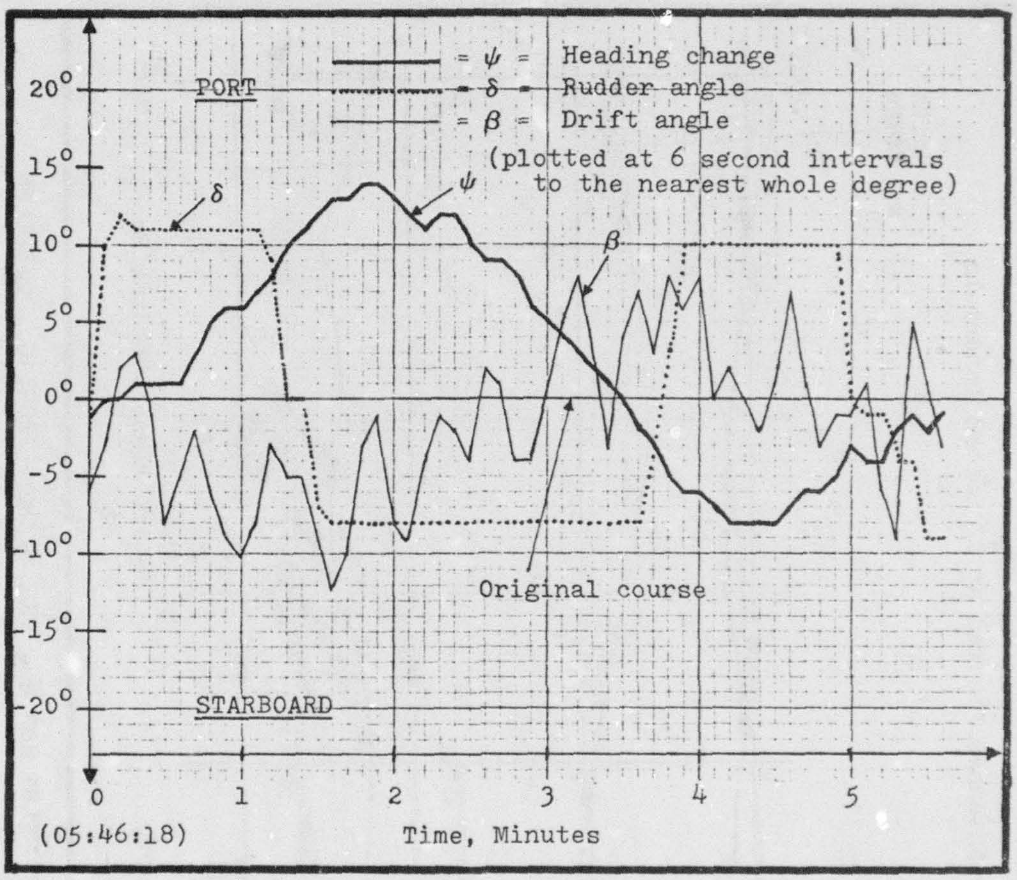


Figure 32. Run 8 - Zig-Zag Maneuver Data

been achieved. Subsequent rudder movements for the zig-zag maneuvers are given in Table 15.

Figure 32 shows the degrees of drift angle, rudder angle, and heading angle change plotted at 6 second intervals to portray the zig-zag maneuvers. This figure shows that the zig-zag maneuvers performed in Run 8 are much less definitive than those performed in Run 5--particularly with respect to rudder movement and heading change. During the first zig-zag maneuver, for instance, the tow's heading had only reached 7^{o} to port when the

starboard rudder movement was initiated. This starboard rudder movement only achieved an opposite angle of approximately 8° which did not match the previous 11° port rudder angle. The next zig-zag maneuver commenced approximately 30 seconds too soon when the tow's heading was only 2° to the right of the initial course line.

These zig-zag maneuver irregularities prevent direct comparison with the upstream zig-zag maneuvers conducted in Run 5. To an extent these problems were anticipated because the magnetic compass in the pilothouse was used to determine the tow's heading and rather large oscillations of the compass card were observed. Also, the pilot had to estimate the amount of rudder to apply and then wait for the rudder angle indicator to display the angle actually achieved.

Table 16 shows the performance statistics obtained during Run 8 for a 355 second period beginning 1 minute prior to the time when the pilothouse was abeam the north range mark. In general, the data indicate that the tow's speed was reduced by approximately 7 percent from the time when the first zig-zag maneuver commenced until the tow was abeam the mid-course range. Maximum drift angles of 7.939° and -12.341° were obtained with an average drift angle of -1.901° for this test run. The tow traveled a distance of 6470.6 feet at an average speed of 10.56 mph through the water with maximum yaw rates of 0.363° and -0.419°/second recorded during the zig-zag maneuvers.

Table 16. Test Run 8 Performance Data
(Full Power, Zig-Zag, Downriver)

Performance Variable	North Leg	Exxon,** Dravo Data
Time, seconds	355	209
Actual distance, feet	6470.6	---
True Course, degrees	179.09	---
Ave. speed over ground, mph	12.43	12.26
" " " " , fps	18.23	17.98
Ave. speed thru water, mph	10.56	---
" " " " , fps	15.49	---
Shaft horsepower, stbd.	1493.7	1496.0
" " , port	1692.5	1705.0
" " , both	3186.2	3201.0
Rudder angle, degrees (Positive to port)		
, minimum	-8.2	---
, maximum	11.9	---
, average	1.1	---
Yaw rate, degrees/second (Positive clockwise)		
, minimum	-0.419	---
, maximum	0.363	---
, average	0.016	---
Drift angle, degrees (Positive to port of C.L.)		
, minimum	-12.34	---
, maximum	7.94	---
, average	-1.90	---
Fuel consumption rate (Pounds/BHP-hour)	---	0.345
Water depth, feet		
, minimum	28.0	---
, maximum	61.9	---
, average	36.6	---

*This data also includes a 60 second approach period in addition to the 295 seconds which elapsed when traversing the North Leg.

**Reference 2.

VII. RANGE MEASUREMENT DATA PROCESSING

The most critical portion of the data processing activities related to the reduction of the range data recorded during the trials into smoothed X,Y coordinates. To accomplish this, the processing sequence shown in Figure 33 was employed with the aid of a computer program composed of modular algorithms to perform the necessary computations. This section focuses on the analytical considerations required to transform the raw range data recorded during the tow trials into a second-by-second mapping of tow movements, positions, and attitudes. Examples of the resulting computerized data are given in Appendix A.

Figure 33 shows two large blocks on the left indicative of the effort required to provide a program-accessible, ordered array of range data located on tape and indexed according to the time and test number of each trial run. The first block portrays the manual editing procedures taken to prepare the recorded range measurements for formatted data entry and magnetic tape storage prior to computer analysis. The second block indicates interactive editing procedures required to check the computer formatted data list and to correct errors due to data translation and key punching.

A series of twelve numbered blocks follow which describe the algorithic sequence of the calculations. The critical nature of this processing sequence is demonstrated by the fact that four range measurements from the trials generated numeric values for 12 dynamic parameters which describe tow motions. Figure 34 lists and describes the parameters computed from the initial range measurements.

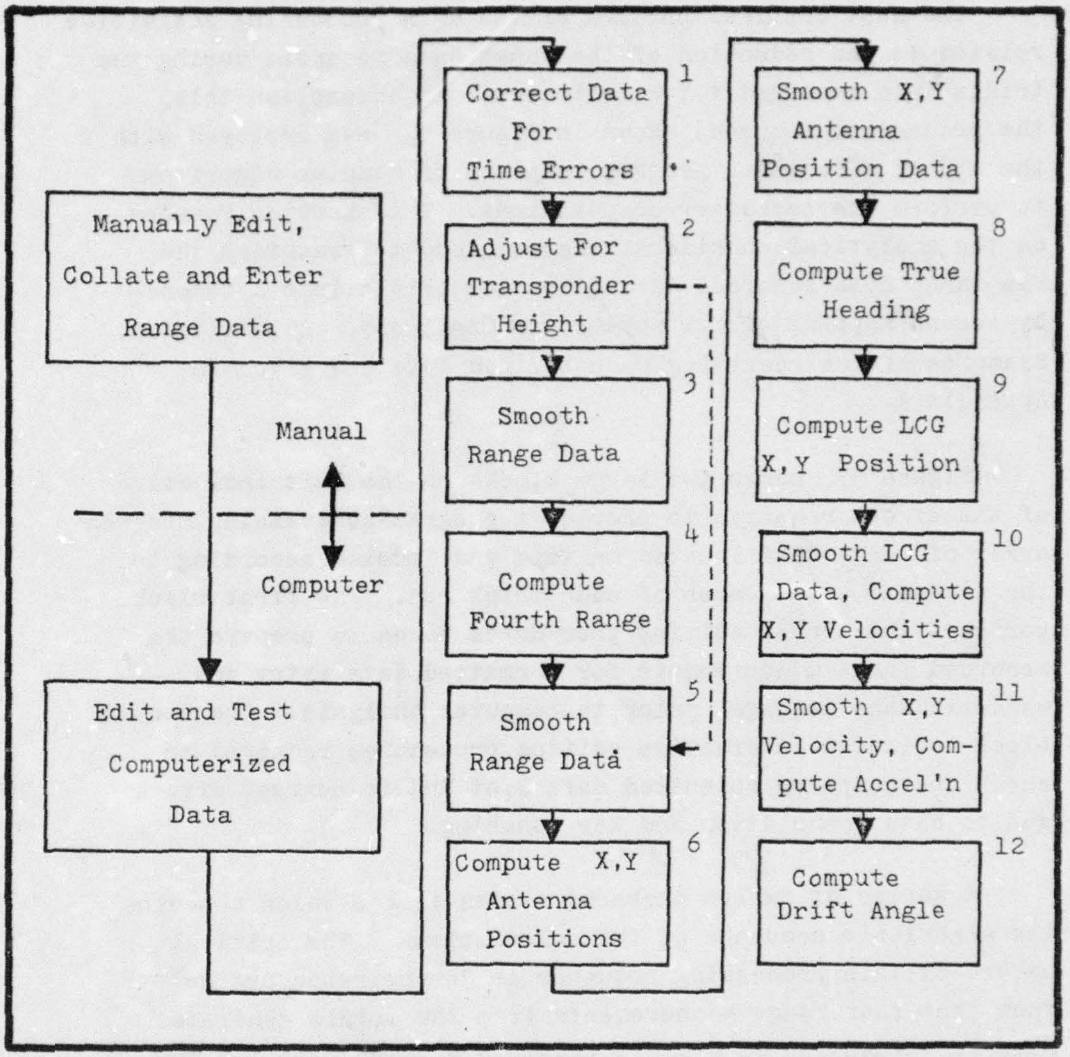


Figure 33. Range Measurement Processing Sequence

Input

- t
- R_1
- R_2
- R_3
- R_4

$\Rightarrow$ Block 1 through 12 Computations (Figure 33) $\Rightarrow$

Output

- $\hat{R}_1, \hat{R}_2, \hat{R}_3, \hat{R}_4$
- X_P, Y_P, X_B, Y_B
- $\psi, \dot{\psi}, \ddot{\psi}$
- $X_G, \dot{X}_G, \ddot{X}_G$
- $Y_G, \dot{Y}_G, \ddot{Y}_G$
- $\beta, U, \dot{U}$

Description

t = time(seconds)

R = Range(meters) between antenna and transponder

X = Geographic north-south axis, positive northward(feet)

Y = " east-west axis, positive eastward(feet)

$\dot{X} = dX/dt$ = velocity(feet/second)

$\dot{Y} = dY/dt$ = " (")

$\ddot{X} = d^2X/dt^2$ = acceleration(feet/second^2)

$\ddot{Y} = d^2Y/dt^2$ = " (")

ψ = true heading angle of the tow(degrees)

$\dot{\psi} = d\psi/dt$ = yaw rate(degrees/second)

$\ddot{\psi} = d^2\psi/dt^2$ = angular acceleration(degrees/second^2)

$U = (\dot{X}^2 + \dot{Y}^2)^{\frac{1}{2}}$ = resultant velocity(feet/second)

$\dot{U} = (\ddot{X}^2 + \ddot{Y}^2)^{\frac{1}{2}}$ = " acceleration(feet/second^2)

β = drift angle(degrees) measured from U to the tow's heading, positive clockwise

Notation

B, subscript denoting bow antenna
P, " " pilothouse antenna
G, " " center of gravity
^, denotes revised or smoothed value

Figure 34. Computed Tow Parameters

The initial range measurements were adjusted and smoothed as shown in Blocks 1 through 5 in Figure 33 to provide second-by-second range measurements $\hat{R}$ between antenna on the tow and transponder ashore. The $\hat{R}$ values were then used to compute X,Y coordinates for the tow antennas in Block 6 given as X_P, Y_P and X_B, Y_B for the pilothouse and bow antennas, respectively. Block 7 smoothed these X_P, Y_P and X_B, Y_B values.

The heading angle ψ, shown by Block 8, was calculated from the smoothed X_P, Y_P and X_B, Y_B data with the angular velocity $\dot{\psi}$ and acceleration $\ddot{\psi}$ obtained by differentiating equations for ψ. Block 9 used the X_P, Y_P coordinates and heading angle ψ to compute coordinates for the tow's center of gravity, X_G and Y_G. The X_G, Y_G values were then smoothed in Block 10 by fitting regression equations to the data to obtain revised values which were differentiated to obtain velocity ($\dot{X}$ and $\dot{Y}$).

Block 11 smoothed the velocity data by fitting linear regressions which were differentiated to provide accelerations, $\ddot{X}$ and $\ddot{Y}$. The drift angle β and resultant velocity and acceleration were computed in Block 12 from the smoothed velocity and heading angle data.

The computations involved in obtaining the above parameters are described in the following sections.

7.1 Preparation of Range Measurements for Processing

Each range reading was manually examined for consistancy to determine if the reading was reasonable. Erroneous readings were, for the most part, easily identified and discarded due to the large numeric difference between successive "valid" readings. The erroneous readings were due primarily to the

inclusion of reflected signals from metallic structures along the test course and off of the tow.

Table 17 shows a sample of the actual range measurements recorded by the pilothouse and bow receivers during the trial. These data were contained in Volume 2 (Part 1 and 2) and Volume 3 of the preceding report [8]. The Table 17 data were taken from Volume 2, Part 1, page 27.

When multiple range entries occurred at a given time, such as shown by the boxed-in values in Table 17, the valid ranges were averaged and rounded to the nearest whole meter. Erroneous datum, which were later excluded, are shown with single lines through the number. The reader will note that most erroneous range values differ from valid ranges by several hundred meters. Occasionally, however, two range readings would fall within expected limits but were excluded--as was the case for the range readings shown for the Pilothouse Receiver-Transponder 1 pair at "023436" and "023437". This was done because selecting one of the values would logically require excluding the other, possibly valid, range.

Following this manual editing precedure, the recorded range data were coded onto 80-column IBM cards, read into the computer and stored on magnetic tape. An example of the computerized data is given by the computer printout shown in Table 18 and contains edited data from Table 17. The clock-time and number seconds used to index the recorded range data are shown in the two left hand columns. The next four columns contain measurements from each transponder-receiver pair which are used to calculate tow position and attitude. Each column shows the distance in meters from a given transponder to the receiving antenna at a given second in time.

Table 17.

Example of Recorded Range Measurements

PILOTHOUSE RECORDER

TIME	TRAN 1	TRAN 2
023458	03369	01506
023457	03364	01508
023456	03364	01511
023455	03363	01515
023454	03356	01520
023454	03353	01523
023453	03351	01527
023452	~~03383~~	01530
023451	03342	01531
023450	03337	01536
023449	03335	~~01059~~
023449	03330	01543
023448	03328.	01547
023447	03326	01551
023446	03320	01553
023445	03320	01556
023445	03313	01560
023444	03310	01562
023443	03306	01566
023442	~~02641~~	01571
023441	03301	01573
023440	~~03151~~	01576
023440	~~03167~~	01580
023439	~~03176~~	01585
023438	~~02983~~	01585
023437	~~03245~~	01589
023436	~~03268~~	01593
023435	~~02716~~	01598
023435	~~03132~~	.01601
023434	~~02570~~	01603
023433	~~03036~~	01607
023432	~~02810~~	01609
023431	~~02719~~	01612
023431	~~03092~~	01617
023430	~~02596~~	01613
023429	~~02940~~	01624
023428	~~02709~~	01526
023427	~~02529~~	01627
023426	~~03071~~	01635
023426	03239	01637
023425	03234	01641
023424	~~03021~~	01643
023423	~~03192~~	01645
023422	03223	01650
023421	03219	01654

BOW RECORDER

TIME	TRAN 1	TRAN 2
023458	~~03389~~	01207
023455	~~02495~~	01217
023452	~~02400~~	01223
023450	~~02945~~	01239
023447	~~02652~~	01246
023444	~~02514~~	01257
023442	~~02408~~	~~19303~~
023439	~~02830~~	01278
023437	~~02394~~	01238
023434	~~02643~~	~~02030~~
023431	03567	01309
023429	~~02910~~	01320
023426	~~03164~~	~~01124~~
023423	03534	01339

Table 18. Computer Printout of Range Data

TIME		BOAT RANGE,MTRS		BUOY RANGE,METERS	
HHMMSS	SECS	TRANS 1	TRANS 2	TRANS 1	TRANS 2
23421	922	3218.0	1655.0	.0	1355.0
23422	923	3225.0	1650.0	.0	.0
23423	924	.0	1646.0	3534.0	1339.0
23424	925	.0	1643.0	.0	.0
23425	926	3234.0	1641.0	.0	.0
23426	927	3238.0	1636.0	.0	.0
23427	928	.0	1627.0	.0	.0
23428	929	.0	1626.0	.0	.0
23429	930	.0	1624.0	.0	1320.0
23430	931	.0	1618.0	.0	.0
23431	932	.0	1614.0	3567.0	1309.0
23432	933	.0	1609.0	.0	.0
23433	934	.0	1607.0	.0	.0
23434	935	.0	1603.0	.0	.0
23435	936	.0	1600.0	.0	.0
23436	937	.0	1593.0	.0	.0
23437	938	.0	1589.0	.0	1288.0
23438	939	.0	1585.0	.0	.0
23439	940	.0	1585.0	.0	1278.0
23440	941	.0	1578.0	.0	.0
23441	942	3301.0	1573.0	.0	.0
23442	943	.0	1571.0	.0	.0
23443	944	3306.0	1566.0	.0	.0
23444	945	3310.0	1562.0	.0	1257.0
23445	946	3315.0	1558.0	.0	.0
23446	947	3320.0	1553.0	.0	.0
23447	948	3326.0	1551.0	.0	1246.0
23448	949	3328.0	1547.0	.0	.0
23449	950	3332.0	1543.0	.0	.0
23450	951	3337.0	1536.0	.0	1239.0
23451	952	3342.0	1531.0	.0	.0
23452	953	.0	1530.0	.0	1228.0
23453	954	3351.0	1527.0	.0	.0
23454	955	3354.0	1522.0	.0	.0
23455	956	3363.0	1515.0	.0	1217.0
23456	957	3364.0	1511.0	.0	.0
23457	958	3364.0	1508.0	.0	.0
23458	959	3371.0	1506.0	.0	1207.0

7.2 Time Correction of Range Measurements

Analysis of the range readings obtained after the tow trials indicated that there were time discrepencies between simultaneous range measurements recorded for the pilothouse and bow receivers. By manually solving for the tow's position using the geometry of the measured ranges and known transponder antenna separation distance, it was possible to compute a distance for antenna separation on the tow. By subtracting the actual from the computed antenna separation distance and dividing this difference by the tow's speed, the time discrepancy between the receiver on the bow and on the towboat was obtained. This gave the relationship shown in the following equation where T_c = the relative time error in seconds between bow and towboat receivers, D_c = the computed antenna separation distances, D_A = the actual antenna separation distance in feet (1038 feet), and U = the velocity of the tow in feet/seconds.

$$T_c = [D_c - D_A]/U = [D_c - 1038]/U \qquad (1)$$

By convention, the correct time was taken to be that recorded by the towboat's receiver. With the towboat moving forward, T_c was negative ($D_c < D_A$) when the clock in the bow receiver was running faster than the clock in the towboat receiver; T_c was positive ($D_c > D_A$) when the bow receiver clock was slower. The bow receiver's time difference was corrected to that of the pilothouse receiver by algebraically adding T_c to the time given by the bow receiver.

Figure 35 shows the manually calculated T_c values as short, heavy vertical lines plotted against the pilothouse receiver time T_p, where the T_p is given as decimal fractions of hours. When plotted, these data showed a relatively constant or linear increase over time due to the probable low input

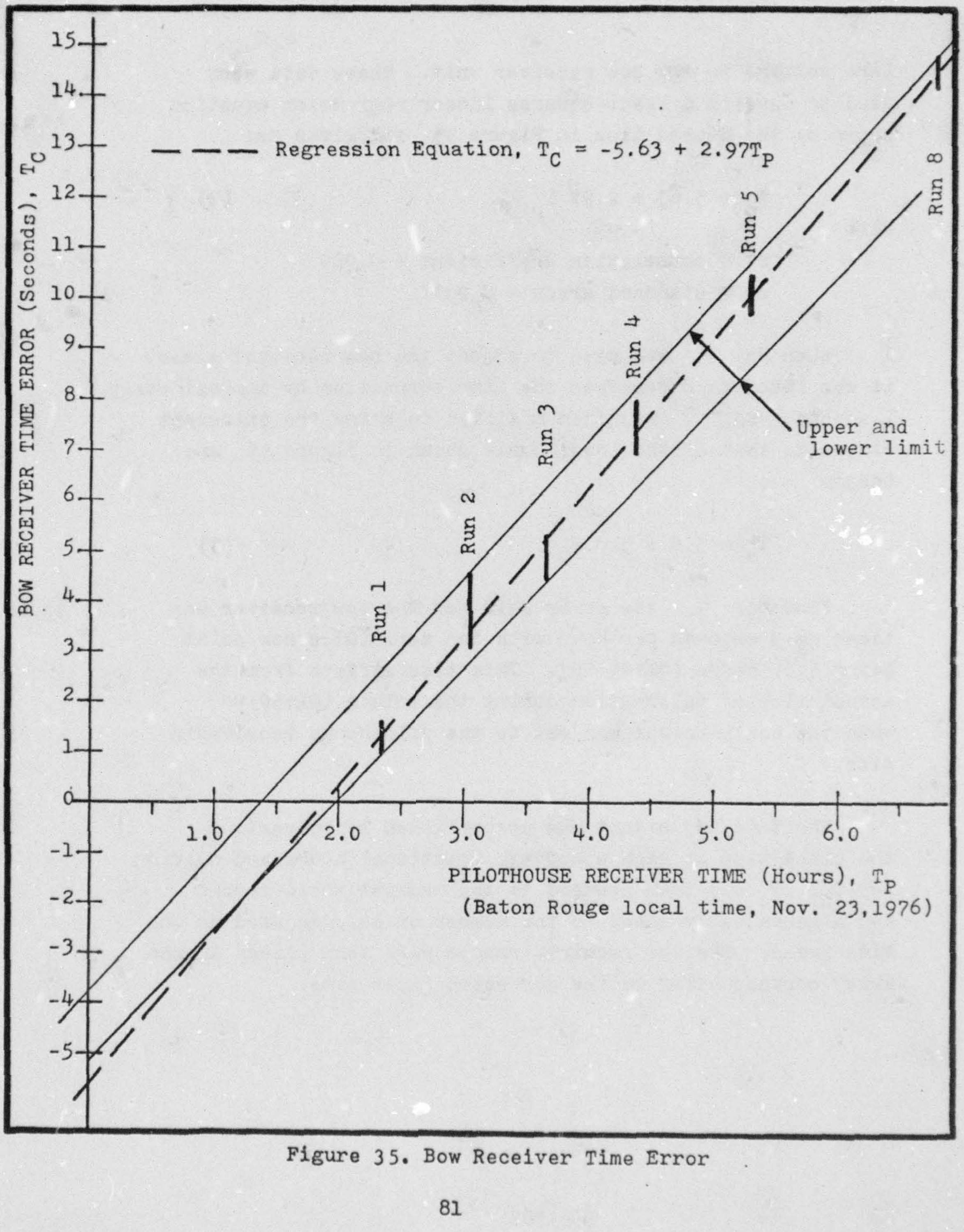


Figure 35. Bow Receiver Time Error

line voltage to the bow receiver unit. These data were used to develop a least-squares linear regression equation shown by the dashed line in Figure 35 and given as:

$$T_c = 5.63 + 2.97\ T_p \qquad (2)$$

with

$$r^2 = \text{correlation coefficient} = 0.989$$
$$s = \text{standard error} = 0.221.$$

When Eq. 2 was used to adjust the bow receiver times, it was found to understate the time correction by approximately 1 second. Eq. 2 was then modified to bring the intercept closer to that of the lower limit shown in Figure 35 and became

$$T_c = 5.0 + 3.0\ T_p\ . \qquad (3)$$

From Eq. 3, the error rate for the bow receiver was taken as 3 seconds per hour with the zero (0) error point being 1.67 hours (01:40:00). This time differs from the actual time of calibration during the trials (01:50:00) when the bow receiver was set to the pilothouse receiver's time.

The time adjustment was accomplished by converting the clock time at each second to fractional hours and solving for T_c. T_c was then rounded to the nearest whole second and algebraically added to the number of seconds used as the time index. The bow receiver ranges were then placed in the array corresponding to the corrected index time.

7.3 Transponder Height Correction of Range Measurements

Of the four transponders used during the test, only Transponder 1 located on the Capitol Building had a significantly different height than the height of the antennas on board the tow. The height difference between Transponder 1 and the tow antennas was taken as approximately 350 feet (106.68 meters) based upon the elevation given for the Capitol Building. The other three transponders were estimated to have vertical height variations of less than 40 feet from the height of the tow antennas. Because these variations introduced a maximum error of less than 0.5 feet in horizontal range readings, well within the 3 meter accuracy of the Miniranger equipment, they were disregarded.

Figure 36 shows the relationship between the measured range (R), the transponder height (H), and the adjusted range ($\hat{R}$) in which the adjusted range is given by

$$\hat{R} = R \cdot \mathrm{Cos}[\mathrm{arcSin}(H/R)] \tag{4}$$

and decreased the Transponder 1 ranges from 1 to 7 meters.

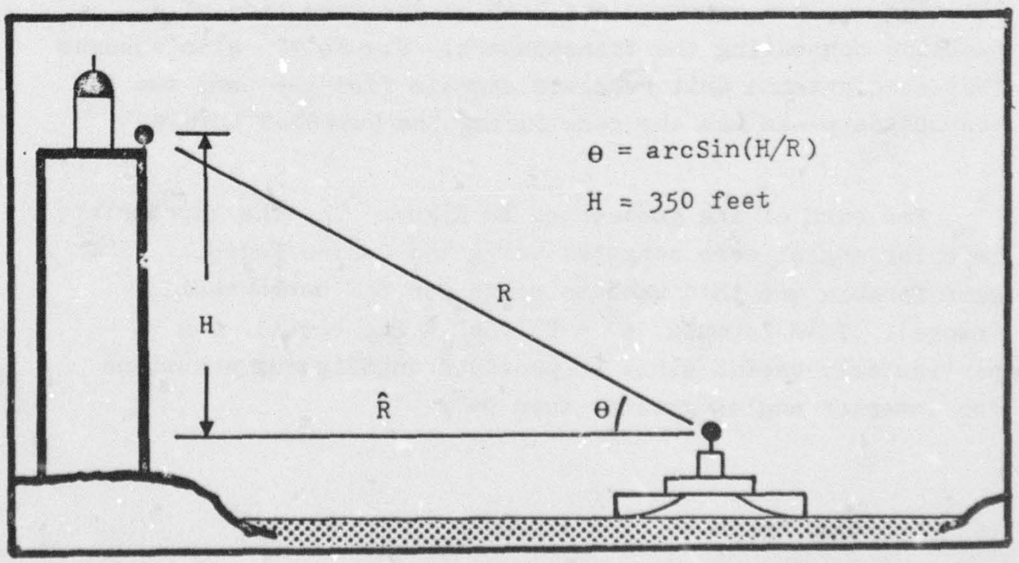


Figure 36. Transponder 1 Height Correction

7.4 Computed Range Measurements

The test program was designed to provide four independent range measurements--two at each antenna on the tow--to establish tow position and attitude in the waterway. Due to signal reflections which distorted range readings at certain points along the test course, periods of time greater than 1 minute occurred where only 3 of the 4 transponders were providing valid data.

To compensate, an algorithm was developed to compute the missing fourth range using the transponder and antenna separation distances and the three other ranges to trigonometrically solve for the fourth. This method, however, provided a nonunique solution. To resolve this ambiguity, a logic variable was specified which identified one of four possible orientations for the tow antennas and transponders.

Figure 37 gives examples of the four possible geometries assuming the tow antennas are both on the same side of a baseline connecting the transponders. Figure 37 also assumes that each antenna unit receives signals from the same two transponders--as was the case during the November trials.

For each of the geometries in Figure 37, the appropriate interior angles were computed using the Cosine Formula. The same formula was then used to solve for the unknown side (range). This formula, $a^2 = b^2 + c^2 - 2bc\cos(A)$, was particularly useful since it provided unambiguous solutions for interior angles greater than 90°.

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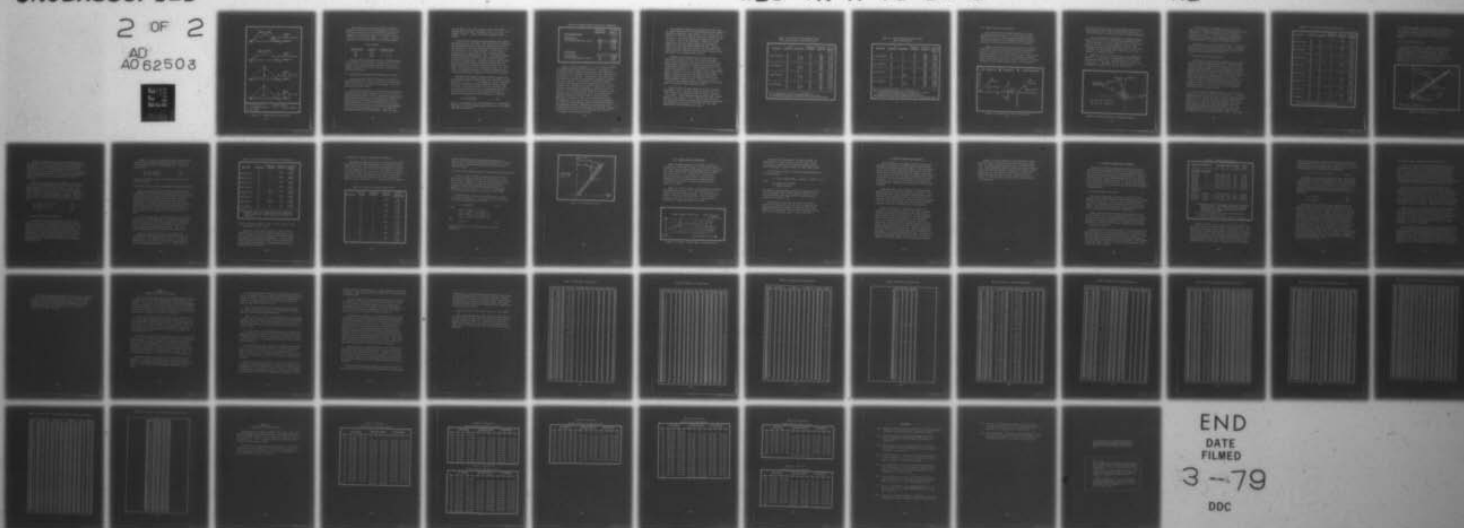

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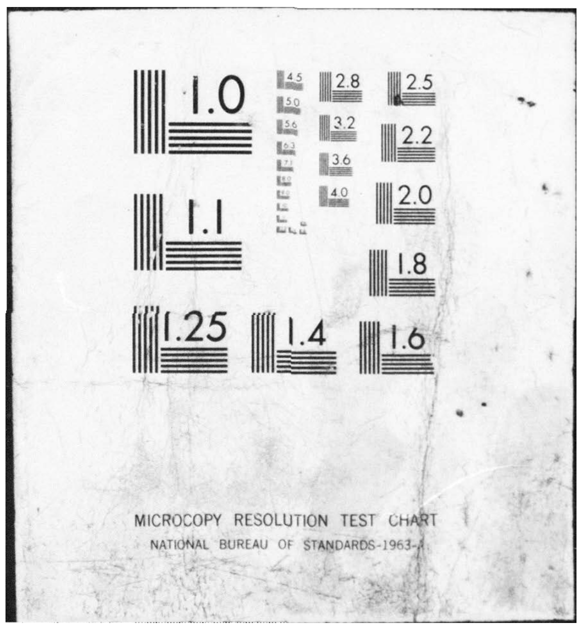
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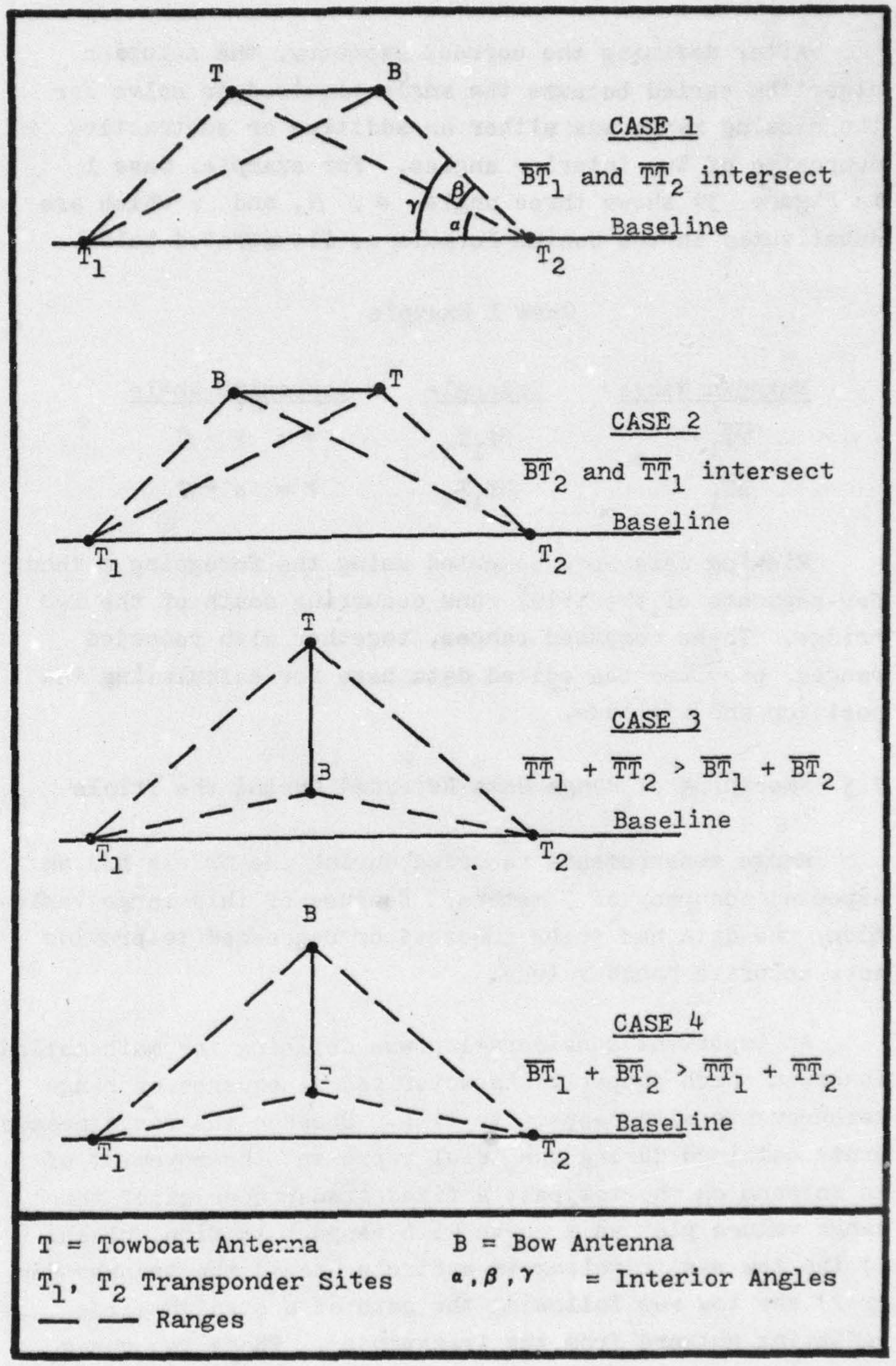


Figure 37. Representative Tow Geometries

After defining the correct geometry, the solution algorithm varied because the angle required to solve for the missing range was either an additive or subtractive composite of two interior angles. For example, Case 1 in Figure 37 shows three angles α, β, and γ which are substituted in the Cosine Formula as illustrated below.

Case 1 Example

Unknown Range	Triangle	Composite Angle
$\overline{TT_1}$	TT_1T_2	$\alpha = \gamma - \beta$
$\overline{BT_1}$	BT_1T_2	$\gamma = \alpha + \beta$

Missing data were computed using the foregoing method for segments of the trial runs occurring south of the 190 Bridge. These computed ranges, together with recorded ranges, provided the edited data base for calculating tow position and attitude.

7.5 Smoothing of Range Data Recorded During the Trials

Range measurements recorded during the trials had an expected accuracy of 3 meters. Because of this large variation, the data had to be smoothed or regressed to provide more accurate range values.

An important consideration was defining the mathematical function which properly characterized a sequence or range measurements with respect to time. Because the range measurements obtained during the trial represent the movement of an antenna on the tow past a fixed transponder site, the range values plot as a curve with respect to time unless: 1) the tow was traveling in a circle around the transponder; or 2) the tow was following the path of a straight line radiating outward from the transponder. These two cases

did not apply to the trials and meant that a non-linear equation should be used. A parabolic form ($R = a + bt + ct^2$, where R = range, t = time) was chosen as being the most robust.

A second factor considered was the method of fitting the smoothing equation to the data. The initial method considered was to sequentially step through the range data by fitting the first half of the curve to previously smoothed data and the second half to the unsmoothed data. Another method considered was to simply step through the unsmoothed data, sequentially fitting regression curves. Each method assumed that the mid-point in the fitted curve would be solved to provide the smoothed value. A number of tests indicated that there were relatively small differences between these two methods and that the critical considerations related to the number of data points and the time span included. For this reason, the simpler technique of fitting a regression curve to unsmoothed data and solving for the mid-point was adopted.

Determining the number of data points and time span for the regression equation required that only odd numbers of data points (5, 7, 9, 11, . . .) be considered. Several regression smoothing tests were made using range data recorded during the trials. Both data recorded at 1 second intervals from the pilothouse receiver and at 2-4 second intervals from the bow receiver were tested. These tests were evaluated in terms of the standard error of the estimate, s, given by:

$$s = [\Sigma(R-\hat{R})^2/N]^{\frac{1}{2}} \qquad (5)$$

where s = the standard error of the estimate, R = the recorded range value, $\hat{R}$ = the estimated range value, and N = the number range values regressed.

Table 19. Example Standard Errors After Regression

	Regression Data Points	Standard Error, s (meters)
Pilothouse Receiver		
• 300 seconds	7	1.741
• 298 data points	11	1.976
• 1.007 second average interval	$\boxed{15}$	$\boxed{2.032}$
	19	2.090
	21	2.127
	23	2.137
	27	2.198
	31	2.262
Bow Receiver		
• 300 seconds	$\boxed{7}$	$\boxed{2.113}$
• 83 data points	11	2.148
• 3.614 second average interval	15	2.107
	19	2.186

Table 19 provides examples of s for a 5 minute segment of recorded data from the first trial run. The effect of including different numbers of data points in the regression is illustrated by comparing regression data from ranges recorded at different time intervals. For instance, range data from the pilothouse receiver were recorded at intervals of slightly more than 1 second. As the number of range measurements included in the regression were increased from 7 to 31, the standard error increased from 1.741 to 2.262 meters. The bow receiver recorded range measurements at intervals of 2 to 4 seconds. As the number of range measurements included in the regression were increased from 7 to 19, the standard error remained reasonable constant between 2.1 and 2.2 meters. Examination of printout lists of the regressed data points indicated that a time span of from 15 to 30 seconds appeared to provide the best compromise between smoothing effectiveness and regression accuracy. Generally, when the average time interval between data points was large (greater than 3 seconds), 7 data points were used. When the interval was very close to 1 second, 15 data points were used.

The regression equations for smoothing were also used to compute range values in intervals where none were recorded. Because the regression logic fitted a curve to data about a mid-point in the curve, missing values were computed for each second of the interval between the mid-point and the next data point. When it was necessary to compute the fourth range from three other range readings (as discussed in Section 7.4), the three known range values were smoothed before the fourth range was computed. The computed fourth range values were then smoothed as indicated in Figure 33 by the dashed line connecting Blocks 2 and 5.

Standard errors obtained from the range smoothing regressions are given in Table 20 for the four straight course, speed-power trial runs and in Table 21 for the four steering runs. Examination of Tables 20 and 21 show that 19 regression passes have s values ranging from 1.5 - 2.0 meters, 8 ranging from 2.0 - 2.5 meters, 6 with values greater than 2.5 meters, and 5 with values less than 1.5 meters. In general, regression data for the computed ranges exhibit smaller standard errors than the regression data for the ranges recorded during the trial. This is due, in part, to the fact that computed ranges are computed for each second while the recorded ranges included time gaps.

Table 21 shows the range values for the Bow Receiver--Transponder 4 pair, required secondary smoothing due to the large standard error obtained during the initial regression. In this case, a second smoothing pass was made using a linear equation of the form $R = a + bt$. Table 21 also shows that the bow receiver tended to produce larger standard errors than the pilothouse receiver due to the fact that fewer range measurements were recorded per unit time.

Table 20. Range Smoothing Regression Data
(Four Straight-Course, Speed-Power Runs)

Trial Run	(a) Receiver	Transponder	Regression Points	Regressed Data, N	Standard Error, s (meters)
1	P	1	15	1055	1.886
(1135 seconds)	P	2	15	1119	1.803
	B	1 (b)	7	296	3.261
	B	1 (c)	15	236	0.674
	B	2	7	371	2.155
2	P	1	15	784	2.684
(880 seconds)	P	2	15	849	1.954
	B	1 (b)	7	392	1.625
	B	1 (c)	15	126	0.709
	B	2	7	278	2.101
3	P	1	15	971	1.748
(1035 seconds)	P	2	15	1014	1.850
	B	1 (b)	7	292	2.024
	B	1 (c)	15	186	2.696
	B	2	7	355	1.946
4	P	1	15	867	1.940
(935 seconds)	P	2	15	915	2.295
	B	1 (b)	7	253	1.976
	B	1 (c)	15	256	0.617
	B	2	7	321	1.692

(a) P = Pilothouse Receiver, B = Bow Receiver
(b) Smoothing only the data recorded during the trial.
(c) Smoothing of ranges computed from other range measurements.

Table 21. Range Smoothing Regression Data
(Four Steering Runs)

Trial Run	(a) Receiver	Transponder	Regression Points	Regressed Data, N	Standard Error, s (meters)
5	P	1	15	940	1.646
(1010 seconds)	P	2	15	992	1.618
	B	1	7	282	3.530
	B	2	7	348	2.068
6	P	3	13	390	1.783
(550 seconds)	P	4	13	502	1.351
	B	3	7	146	3.122
	B	4	7	176	1.507
7	P	3	13	392	1.858
(590 seconds)	P	4	13	548	1.615
	B	3	7	142	2.309
	B	4 (b)	7	188	5.763
	B	4 (b)	7	590	0.872
8	P	1	15	344	2.279
(415 seconds)	P	2	15	401	1.626
	B	1 (c)	7	103	1.934
	B	1 (d)	15	183	1.736
	B	2	7	145	2.250

(a) P = Pilothouse Receiver, B = Bow Receiver
(b) Due to the large initial error (5.763 meters), a second smoothing pass was made using a linear form.
(c) Smoothing only the data recorded during the trial.
(d) Smoothing of range data computed from other range measurements.

7.6 Compute Antenna X,Y Positions

After smoothing the recorded range data, two range measurements were available for each tow antenna at each second of the trials. These range measurements together with known transponder X,Y coordinates provided the data to compute the tow's position and attitude in the waterway.

Figure 38 shows the required translation of reference axes from the plane coordinate system used by the Geodetic Survey to a system used to describe vehicle motion [9]. Previous sections of the report (Sections III, V, and VI) gave geographic positions in terms of X,Y coordinates typically used in surveying in which X was positive eastward, Y positive northward, and Z positive upward from the earth's surface.

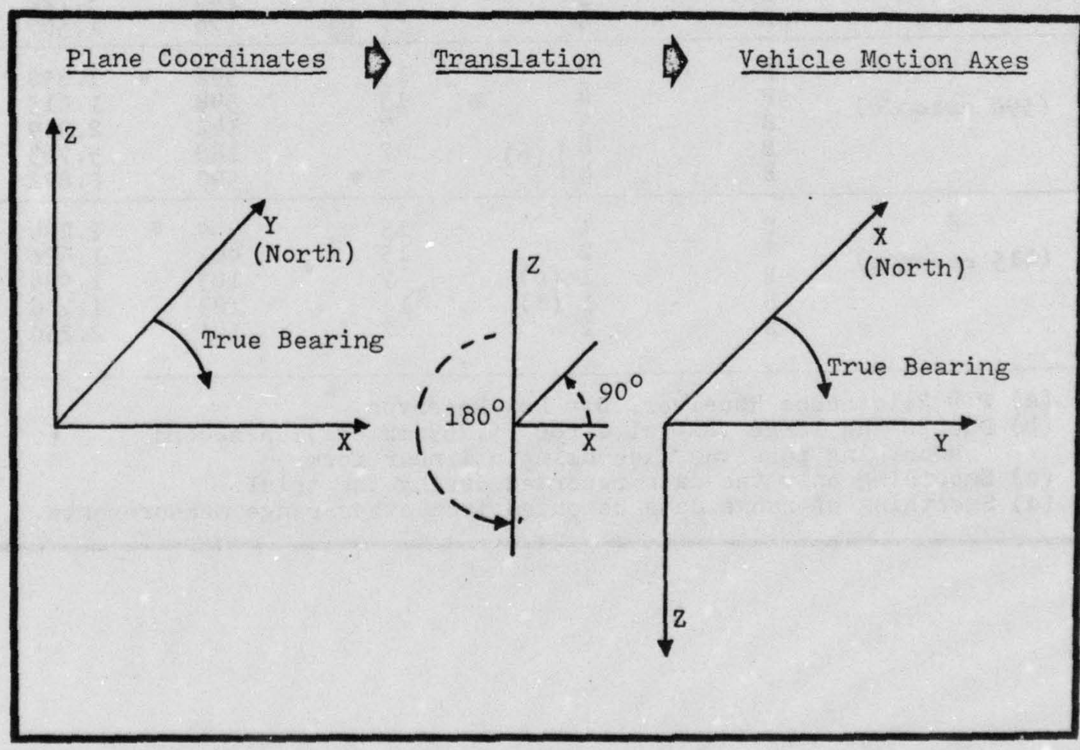


Figure 38. Translation of Plane Coordinate Axes

Using this coordinate system, bearing angles measured clockwise from North (the Y axis) conflicted with traditional vehicle motion axes in which the Z axis was positive downward.

The translation was accomplished by changing coordinate labels (X to Y, Y to X). The resulting coordinates were X positive northward, Y positive eastward, and Z positive downward in the direction of increasing water depth. True bearings, measured clockwise from north (000° to 360°), were consistant with the commonly used "right-hand screw rule" notation for angular direction.

Figure 39 gives the solution geometry for antenna X,Y positions. T_1 and T_2 are the transponder positions, and D the distance between them. The true bearing of T_2 from T_1 is given as θ. The ranges from the tow's antenna (A) to the transponders are given as R_1 and R_2, respectively.

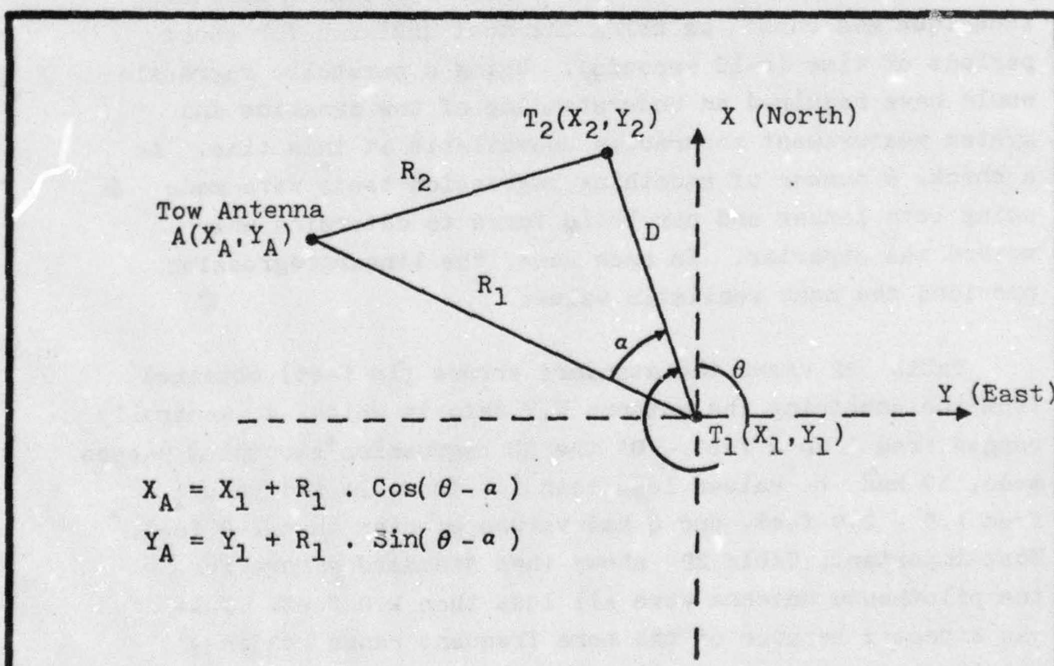


Figure 39. Typical Antenna and Transponder Geometry

Given 3 sides of the triangle, R_1, R_2, and D, the angle α can be computed using the Cosine Formula (Section 7.4) and added to or subtracted from θ to solve for antenna coordinates, X_A and Y_A. The location of the transponder and tow antenna relative to the transponder baseline (D) determines whether α is added to or subtracted from θ.

Computing X_A and Y_A values shown in Figure 39 required that R_1 and R_2 be converted from meters to feet. Following this conversion, X_A, Y_A coordinates are calculated for each antenna at every second of the trial run.

7.7 Smooth Antenna X,Y Position Data

The antenna X,Y positions were smoothed using a linear regression and solving for the mid-point. This reduced the "wobble" caused by computing X and Y values from two independently smoothed ranges. The linear regression smoothing technique was chosen as being the most unbiased for short periods of time (6-10 seconds). Using a parabolic regression would have required an understanding of tow dynamics and system measurement accuracies unavailable at this time. As a check, a number of smoothing regression tests were made using both linear and parabolic forms to determine which method was superior. In each case, the linear regression provided the most realistic values.

Table 22 shows the standard errors (in feet) obtained from the smoothing the antenna X,Y data in which s generally ranged from 1 to 2 feet. Of the 32 regression smoothing passes made, 10 had s values less than 1.0 foot, 16 had values from 1.0 - 2.0 feet, and 6 had values greater than 2.0 feet. Most important, Table 22 shows that standard errors for the pilothouse antenna were all less than 2.0 feet. This was expected because of the more frequent range readings obtained by this unit during the trials. Also, of note were

Table 22. X,Y Antenna Regression Smoothing Data

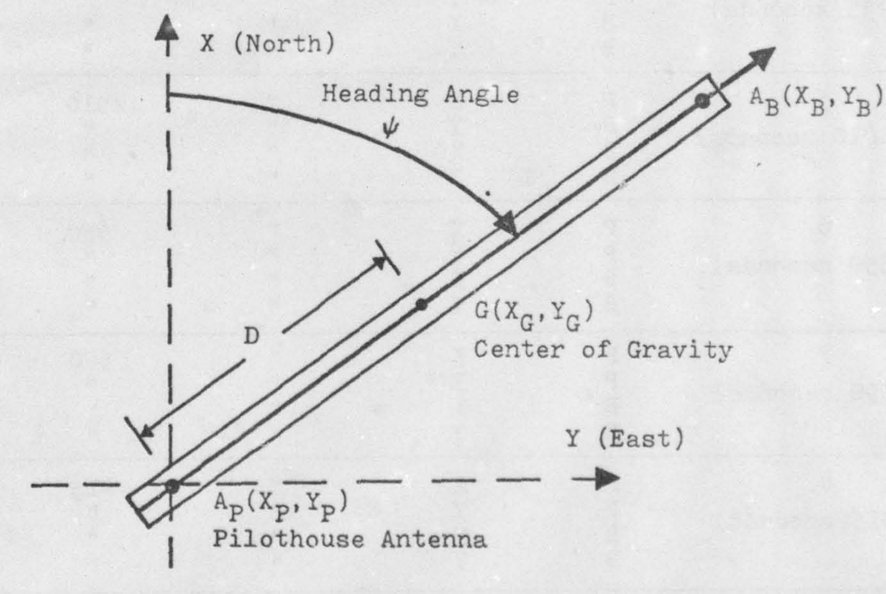
Trial Run	Antenna (a)	Coordinate	Regression Points	Regressed Data, N	Standard Error, s (feet)
1	P	X	7	1135	0.815
(1135 seconds)	P	Y	"	"	1.571
	B	X	"	"	1.145
	B	Y	"	"	2.311
2	P	X	"	880	0.860
(880 seconds)	P	Y	"	"	1.662
	B	X	"	"	1.062
	B	Y	"	"	1.793
3	P	X	"	1035	0.740
(1035 seconds)	P	Y	"	"	1.597
	B	X	"	"	0.983
	B	Y	"	"	2.200
4	P	X	"	935	0.957
(935 seconds)	P	Y	"	"	1.733
	B	X	"	"	0.909
	B	Y	"	"	2.027
5	P	X	"	1010	0.706
(1010 seconds)	P	Y	"	"	1.503
	B	X	"	"	0.976
	B	Y	"	"	2.967
6	P	X	"	550	1.051
(550 seconds)	P	Y	"	"	1.584
	B	X	"	"	1.388
	B	Y	"	"	2.582
7	P	X	"	590	1.170
(590 seconds)	P	Y	"	"	1.168
	B	X	"	"	1.519
	B	Y	"	"	1.770
8	P	X	"	415	0.722
(415 seconds)	P	Y	"	"	1.886
	B	X	"	"	0.928
	B	Y	"	"	2.530

(a) P = Pilothouse Antenna B = Bow Antenna

the consistantly higher s values for the Y coordinate at both antennas. These larger errors were most noticeable for trial runs 1 through 5 and trial run 8 when the tow was travelling in a north-south direction (primarily along the X axis).

7.8 True Heading Calculation

The tow's attitude in the waterway is determined by computing its true heading angle using the smoothed antenna X,Y data described in the previous section. Figure 40 shows the geometry of the tow and graphically depicts the relationship between the antennas and heading angle. The X-axis is shown as the north-south axis with the tow's true heading angle (ψ) drawn to the tow's centerline.



$$\mathrm{Tan}(\psi) = (Y_B - Y_A)/(X_B - X_A)$$

Figure 40. Heading Angle Geometry

Because the antennas were located approximately along the centerline of the tow, computing the true heading involved determining the bearing angle of the bow antenna from the pilothouse antenna. This bearing angle was taken as the angle measured clockwise from the X axis to the line connecting the pilothouse and bow antenna. This angle was then adjusted because the two antennas were not parallel to the tow's centerline.

After the heading angles were computed for each second of a trial run, these angles were made functions of a second degree equation in time (t) given by Eq. 6 below. The three coefficients (a, b, c) were solved using simultaneous equations given 3 adjacent values for t and ψ. The yaw rate ($\dot{\psi}$ in Eq. 7) and the angular acceleration ($\ddot{\psi}$ in Eq. 8) were the first and second derivatives evaluated at the midpoint.

$$\psi = f(t) = a + bt + ct^2 \qquad (6)$$

$$\dot{\psi} = f'(t) = b + 2ct \qquad (7)$$

$$\ddot{\psi} = f''(t) = 2c \qquad (8)$$

7.9 Center of Gravity X,Y Coordinates

The distance between the Miniranger antennas and key points on the tow were determined from measurements taken when the antennas were installed prior to the trials. These measurements together with dimensional data describing the tow, were used to locate the center of gravity relative to each antenna. These relationships combined with the second-by-second antenna X,Y and heading angle data provided X,Y coordinates for the tow's center of gravity at each second during the trial.

Figure 40 depicts the geometry used to locate the tow's center of gravity $G(X_G, Y_G)$ from the position of the pilothouse antenna (A_p) and the heading angle (ψ). X_G and Y_G are given by:

$$X_G = X_p + D \cdot \mathrm{Cos}(\psi) \qquad (9)$$

$$Y_G = Y_p + D \cdot \mathrm{Sin}(\psi) \qquad (10)$$

where D is the distance from the pilothouse antenna to the center of gravity.

7.10 Smooth Center of Gravity Coordinates and Compute Velocity

Major end products from the computer analysis were the specification of tow velocities and smoothed center of gravity coordinates for each second of the trial runs. The center of gravity coordinates required smoothing because they were calculated from independently derived bow and pilothouse coordinates. The linear regression equations used to smooth the coordinates were differentiated to obtain velocity. The fitted equation and its first derivative were evaluated at the mid-point to give the smoothed coordinate and velocity data.

The linear regression, used for smoothing, fitted 5 data points over a 4 second time span. This time span was chosen because it was shorter than the 6 seconds used in smoothing the bow and pilothouse antenna coordinates from which the center of gravity coordinates were derived. Also, the 4 second time span produced no artifical flattening of data.

Table 23 shows the standard errors obtained from smoothing the X_G and Y_G data for the eight trial runs. For the most part, s ranged between 0.1 and 0.4 feet with X_G having a much larger standard error than the Y_G coordinate. Of the 16 smoothing passes made, 5 had s values under 0.2

Table 23. Center of Gravity Regression Smoothing Data

Trial Run	Coordinate	Regression Points	Regressed Data, N	Standard Error, s (feet)
1 (1135 seconds)	X	5	1135	0.179
	Y	"	"	0.307
2 (880 seconds)	X	"	880	0.196
	Y	"	"	0.285
3 (1035 seconds)	X	"	1035	0.162
	Y	"	"	0.294
4 (935 seconds)	X	"	935	0.231
	Y	"	"	0.322
5 (1010 seconds)	X	7 (a)	1010	0.292
	Y	" (a)	"	0.705
6 (550 seconds)	X	5	550	0.179
	Y	"	"	0.345
7 (590 seconds)	X	7 (a)	590	0.859
	Y	" (a)	"	0.684
8 (415 seconds)	X	5	415	0.168
	Y	"	"	0.379

(a) Examination of X and Y velocities from the regression equation using 5 data points showed large second-to-second variations. Using 7 data points reduced this variation.

feet, 8 had values between 0.2 and 0.4 feet, and only 3 had s values greater than 0.4 feet.

Trial runs 5 and 7 shown in Table 23 were initially smoothed using 5 data points. However, examination of the X and Y velocities ($\dot{X}$ and $\dot{Y}$) resulting from differentiating the regression equations showed uncharacteristically large second-to-second variations. When 7 data points were used in the smoothing regression, the resulting $\dot{X}$ and $\dot{Y}$ values appeared much more realistic.

7.11 Smooth X,Y Velocity and Compute Acceleration

The method of deriving the X and Y acceleration ($\ddot{X}$ and $\ddot{Y}$) was similar to the method employed in the previous section to derive velocities. The velocity data were smoothed by fitting a linear regression ($\dot{X},\dot{Y} = a + bt$) to five consecutive points (4 second time span) and solving for the mid-point to provide new $\dot{X}$ and $\dot{Y}$ values. Differentiating the above equation with respect to time provided values for the tow's acceleration along the X and Y axes ($\ddot{X},\ddot{Y} = b$). Table 24 shows the standard

Table 24. Velocity Smoothing Regression Data

Trial Run	Velocity Vector	Regression Points	Regressed Data, N	Standard Error, s (feet/second)
1	$\dot{X}$	5	1135	0.047
	$\dot{Y}$	"	"	0.085
2	$\dot{X}$	"	880	0.050
	$\dot{Y}$	"	"	0.078
3	$\dot{X}$	"	1035	0.046
	$\dot{Y}$	"	"	0.085
4	$\dot{X}$	"	935	0.065
	$\dot{Y}$	"	"	0.090
5	$\dot{X}$	"	1010	0.048
	$\dot{Y}$	"	"	0.113
6	$\dot{X}$	"	550	0.051
	$\dot{Y}$	"	"	0.092
7	$\dot{X}$	"	590	0.099
	$\dot{Y}$	"	"	0.081
8	$\dot{X}$	"	415	0.045
	$\dot{Y}$	"	"	0.104

errors obtained from the velocity smoothing regressions. Only 2 of the 16 smoothing calculations resulted in s values greater than 0.1 feet/second and none had values less than 0.04 feet/second.

7.12 Drift Angle, Resultant Velocity and Acceleration Calculations

The drift angle (β) is the angle formed by the intersection of the resultant velocity (U) and centerline of the tow as shown in Figure 41. The drift angle is measured from U to the tow's centerline and is positive when measured clockwise, negative when measured counter-clockwise. The magnitude of U is given by $U = (\dot{X}^2 + \dot{Y}^2)^{\frac{1}{2}}$. The magnitude of the resultant acceleration is given as $\dot{U} = (\ddot{X}^2 + \ddot{Y}^2)^{\frac{1}{2}}$.

Computationally, β is solved at each second of a trial run by first determining the true direction of U, defined as θ and given in degrees, as shown below.

$$\theta = \arctan(\dot{Y}/\dot{X}) \qquad (11)$$

where

1) $\dot{X} \geq 0$ and $\dot{Y} \geq 0$, $\theta \leftarrow \theta$,
2) $\dot{X} \leq 0$ and $\dot{Y} \geq 0$, $\theta \leftarrow 180^\circ - \theta$,
3) $\dot{X} \leq 0$ and $\dot{Y} \leq 0$, $\theta \leftarrow 180^\circ + \theta$,
4) $\dot{X} \geq 0$ and $\dot{Y} \leq 0$, $\theta \leftarrow 360^\circ - \theta$;

and,

$$\beta = \psi - \theta \, . \qquad (12)$$

When β is positive, U is on the port side of the tow's centerline.

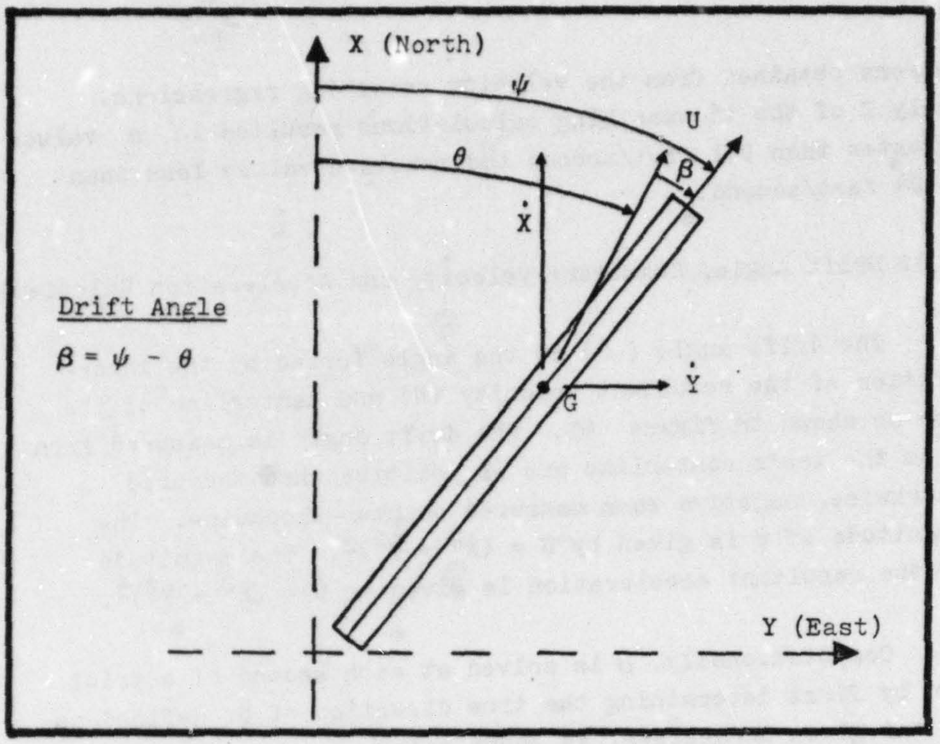


Figure 41. Drift Angle of Tow

VIII. RUDDER ANGLE DATA PROCESSING

Rudder movements during the trials were recorded as voltages on a strip-chart recorder. These voltages (which varied with steering system displacement) were then translated into rudder angles using a nomograph constructed to match the voltage scale of the recorder with a mathematical function relating the rudder angles to steering system displacements. This relationship was checked against voltage and rudder angle calibration measurements made prior to the trials.

Figure 42 gives an example of the strip chart recordings obtained during the trials. The vertical axis gives the voltage in 100 millivolts increments. The hortizontal axis gives the time in 1 second increments. The 1 millimeter division on the chart correspond to a recording speed of 1 millimeter per second used during the trials.

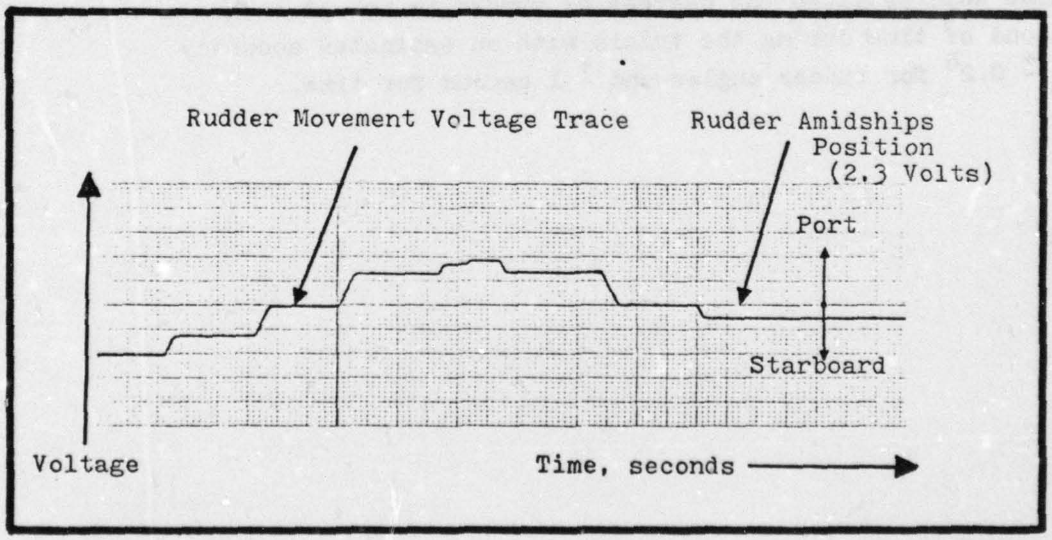


Figure 42. Example of Rudder Angle Voltage Recording

The horizontal centerline of the chart in Figure 42 corresponds to a rudder amidships position and a voltage of 2.3 volts. Values above the centerline measure port or left rudder angles; below, starboard or right rudder angles.

Eq. 13 below was used to translate voltage measurements into rudder angles.

$$\delta = -70.2 + \arccos(0.8845 - 0.2058V - 0.0137V^2) \quad (13)$$

where

δ = rudder angle, degrees

V = measured voltage .

This equation employed common notation for angluar direction in which clockwise (port) rudder movements relative to the tow's longitudinal axis were positive; counter-clockwise movements were negative [9].

Rudder angle and time data for each trial run were coded onto 80-column IBM cards and stored on magnetic tape. These data provided the degrees of rudder in use at each second of time during the trials with an estimated accuracy of $\pm$ 0.2° for rudder angles and $\pm$ 1 second for time.

IX. ENGINE PARAMETER DATA PROCESSING

The performance of the engines during the trials were measured by two primary variables--shaft horsepower (SHP) and shaft revolutions per minute (SRPM). These measurements were recorded by Dravo personnel approximately once every minute for both the starboard and port engines during seven of the eight trial runs. No engine measurements were taken for trial run 7, the southbound trial run around Wilkinson Point bend. For this run, the engines were maintained at an approximately constant speed and values for SHP and SRPM estimated.

After the trials, Dravo processed the recorded engine data and furnished these data to RMSA. In addition to the SHP and SRPM data, engine horsepower (BHP) and engine revolutions per minute (ERPM) data were also provided for each engine at one minute intervals. These data, given in Appendix B , were coded onto 80-column IBM cards, entered into the computer, and placed on magnetic tape for processing.

Computer processing of engine data was limited to providing a second-by-second array of SHP, SRPM, and ERPM values for each engine conforming to the format adopted for the tow position and rudder angle data. To obtain measurements for each second, a polynomical of the form SHP = $a + bt + ct^2$ was solved using simultaneous equations for three adjacent SHP values. The resulting equation was then used to calculate SHP values for each second of time in the interval between recorded SHP values. Similar computations were made on the other variables resulting in estimates for each engine at each second during the trials. The values for the port and starboard engines were then added (for SHP) or averaged (for SRPM and ERPM) to obtain combined performance.

Appendix A contains examples of the computerized engine data with Table A.3 showing the data prior to processing and Table A.10 showing the final form of the computerized engine data. Engine horsepower (BHP) was omitted to conserve computer space since SHP was considered a constant 98 percent of BHP. ERPM could have been omitted as well because the ratio of ERPM to SRPM was constant at 3.47:1. ERPM was included, however, to provide a more complete array of towboat performance parameters.

X. WATERWAY PARAMETER DATA PROCESSING

While most of the data processing activities related to obtaining second-by-second measures of tow performance such as speed, attitude, and position, a significant amount of effort was spent developing second-by-second descriptions of the waterway environment. These waterway parameters were, for the most part, extrapolated from river charts of the area showing depth and river bank and bottom contours. The limited current measurements taken prior to the trials were the only waterway parameters actually measured.

10.1 Current Velocity Calculations

The current measurements described in Section III were obtained at two locations along the test course as shown by boxed in values in Table 25. The first current measurements were taken at the Transponder 2 site between the north range and 190 Bridge. The second measurements were taken in the mid-channel area of Wilkinson Point bend south of Transponder 4.

These current data were then plotted and averaged to give current velocity vectors at two geographic points in the river. The vectors were then compared with the river depth profiles [10] at these two points to determine if the computed current path was parallel to the maximum flow path indicated by the profiles --in each case they were.

Based upon this and using Reference 10, an estimated current path was drawn from one end of the trial area to the other which passed through the two measured current points. Tangents to this path were drawn at nine points (three in the bend area and six in the straight course area) and the true direction of the tangents taken from a chart. Table 25 lists the true direction of the current for these locations.

Table 25. Current Velocity Data

River Coordinates, ft[a]		Velocity, fps[b]			Direction	Area[c]
X	Y	V_c	$\dot{X}$	$\dot{Y}$	T, deg.	A, ft^2
Straight Test Course						
651,100	---	2.88	-2.87	0.20	176	77,500
653,000	---	2.90	-2.90	-0.05	181	73,500
656,500	---	2.77	-2.72	-0.53	191	96.500
659,700	---	2.76	-2.71	-0.53	191	98,750
662,900	---	2.87	-2.87	0.05	179	78,500
665,400	---	2.80	-2.77	0.39	172	91,000
Bend Area						
671,400	43,000	2.82	-2.72	0.73	165	88,000
674,000	41,400	2.20	-1.29	1.78	126	198,000
674,700	39,100	2.24	0.52	2.22	84	191,750

a. Transformed Lambert Coordinates with X positive north, Y positve east. Y values are equivalent to Lambert X minus 2 x 10^{-6} feet. Y values for the straight test course were omitted because the river had a north-south orientation.

b. $V_c = (\dot{X}^2 + \dot{Y}^2)^{\frac{1}{2}}$ where $\dot{X}$ is the velocity along the X axis, $\dot{Y}$ along the Y axis.

c. These data estimated to be accurate to $\pm$ 5 percent.

Having determined current direction (T) along the river, the next step was to estimate current velocity variations. This was done by comparing the approximate cross-section area of the river at the two points where current velocity had been measured. In the Wilkinson Point bend area, the measured current velocity was 2.2 feet/second and the estimated cross-sectional area of the river was 198,000 square feet. South of the 190 Bridge, the measured current velocity was 2.8 feet/second and the estimated

cross-sectional area of the river was 91,000 square feet. These data were used to solve a simple linear equation with V_c, the current velocity in feet/second, made a function of A, the river cross-sectional area in square feet, and given by

$$V_c = 3.31 - (5.61 \times 10^{-6}) \cdot A \ . \tag{14}$$

Reference 10 was used to estimate the cross section areas at seven additional points along the test course. These values, shown in Table 25, were then used in Eq. 14 to calculate the corresponding current velocities shown as V_c in Table 25. The velocity components along the X and Y axes ($\dot{X}, \dot{Y}$) were then computed from the current direction (T) and velocity (V_c) data as follows:

$$\dot{X} = V_c \cdot \cos(T); \tag{15}$$

$$\dot{Y} = V_c \cdot \sin(T) \ . \tag{16}$$

The $\dot{X}$ and $\dot{Y}$ data in Table 25 were incorporated in the computer program to estimate the current effect felt by the tow as it moved over the test course. The position of the bow was used to compute the river current felt by the tow for each second of a trial run. This was done using the bow antenna's X coordinate to interpolate between the X coordinates for the current data given in Table 25. Because the X coordinate of the bow was never greater than 674,700 in the bend area and because the course of the river was parallel to the X axis over the straight course trial area, interpolation with respect to the Y axis was not required. When the X position of the bow was less than (south of) 651,100, the current was assumed constant at $\dot{X}$ = 2.87 feet/second and $\dot{Y}$ = 0.20 feet/second. Examples of the resulting computerized current data are given in Appendix A, columns 35 and 36 of Table A.10.

10.2 Depth of Water, Distance from Bank Calculations

During the trials, the tow's movement along the river was influenced by the depth of water through which it traveled as well as the distance between it and the river banks on each side. It was hoped that depth measurements could be obtained from fathometer readings during the trials and incorporated directly into the computerized tow trial data base. This was not possible because the fathometer in the pilothouse was difficult to read without interfering with the pilot during the trials.

As a result, the water depth and bank distance data incorporated in the trial data base were obtained by plotting the positions of the pilothouse and bow antennas at about 1 minute intervals for each trial run on the charts contained in Reference 10. These charts gave relatively well defined river bank contours which allowed the distance between each bank and the plotted antenna positions to be measured. These distances were estimated to be within 25 feet of the actual distance between bank and tow.

Depth of water at the plotted tow positions were interpolated from these same charts. Cross-sectional depth profiles were given approximately every 1000 feet along the test course with the depth of the water shown in feet at 100 foot intervals across the river. The resulting depth data were estimated to be accurate to $\pm$ 5 percent when corrected for the 5.6 foot gage reading at the time of the trials.

The distances between bank and tow, the interpolation depths, and the corresponding trial times for each run were coded onto 80-column IBM cards and stored as digital records on magnetic tape. Examples of the initial computerized depth data are shown in Appendix A, Table A.3, columns 37 and 38. Examples of the initial computerized data giving the distances between pilothouse and bow antennas and each river bank are given in Table A.4 of Appendix A.

Because these data were obtained at about 1 minute intervals, a "three-point" interpolation algorithm in the computer program was used to calculate values for each second of a trial run. Examples of the final data were given in Appendix A, in Table A.10 for water depth, and in Table A.11 for the distances between the tow and river banks.

APPENDIX A.
Computerized Trial Data Examples

This section contains examples of the digital computer records developed from the tow trial measurements. The purpose of this section is to show the evolutionary nature of the data processing activity undertaken in this project using printouts of 106 seconds of recorded data from the first part of Run 1 as tabular examples. Sections VII through X of the report describe the data processing sequence used to generate the tables in Appendix A.

Each of the following tables are taken from 2 standard 11" x 15" printout pages generated by the report writing section of the computer program. The tables have literal column descriptions at the top with the columns numbered at the bottom from 1 to 42. The local time of each trial (hours:minutes:seconds) is given in the left hand column of each table with the data record index time (in seconds) next to it.

The report writer used four page formats to list the data. The first page format contains 12 numbered columns with the edited Mini-ranger ranges in columns 1 through 4, the adjusted and smoothed ranges in columns 5 through 8, and the smoothed tow antenna X,Y coordinates in columns 9 through 12. Note, the X and Y axes are not Lambert coordinates but refer to the transformed axes in which X is positive north and Y is positive east. In these tables, Y is the transformed Lambert X coordinate with 2×10^6 feet subtracted.

The second page format contains 13 columns numbered from 13 through 25. Columns 13 through 24 give tow position, heading, velocity, and acceleration data typically used to describe vehicle motion. Column 25 gives the rudder angles recorded during the trials.

The third page format contains 13 columns numbered from 26 to 38. Columns 26 through 34 contain engine measurements obtained during the trials. Columns 35 and 36 contain the computed X,Y current velocities and columns 37 and 38 the chartered river depth at the bow and stern of the tow.

The fourth page contains four columns numbered from 39 to 42. These columns list the distance in feet between the river banks and the pilothouse and bow antennas.

Tables A.1, A.2, A.3 and A.4 (corresponding to the four page formats) show the digitized data base at the start of the computer processing sequence. These tables show that only 17 of the 42 columns contained data; and, much of this data at intervals of a minute or more.

The first step in the processing sequence was to adjust the range measurements in columns 1, 3, and 4 for the time and height differences and place the new range values in columns 5, 7, and 8 as shown in Table A.5. The range data in column 2 did not require these adjustments.

The next processing step smoothed the adjusted range measurements and used the regression equations to compute ranges where none were recorded. The results of this step were shown in Table A.6 with columns 5-8 completely filled with non-zero range values. The range data in column 2 were placed in column 6 after smoothing.

Next, the smoothed range values in columns 5-8 and the known transponder coordinates were used to compute the geographic X and Y coordinates for the pilothouse and bow antennas. These computed coordinates were then smoothed as shown by the values in columns 9-12 in Table A.7. The data in columns 9-12 of Table A.7 form the

primary position descriptors used to compute parameters describing tow motion. Table A.7 also lists the final form of the data stored on magnetic tape.

The next steps use the smoothed antenna X,Y data to compute tow heading, yaw rate, and yaw acceleration (column 15, 19, and 24, respectively). The heading angle and pilothouse antenna coordinates are then used to compute the X and Y coordinates for the tow's center of gravity (columns 13 and 14). The values obtained from these tow steps are shown in Table A.8.

Following the computation of the coordinates for the center of gravity, the next step smoothed this data and differentiated the smoothing regression equations to obtain the tow's X and Y velocities (given in columns 16 and 17). These velocities were then smoothed with the smoothing equations differentiated to obtain the X and Y accelerations listed in columns 21 and 22. Resultant velocities and accelerations were then computed for columns 18 and 23, respectively. The smoothed velocity data in columns 16 and 17 and heading angle data in column 15 were then used to compute the tow's drift angle in column 20. These steps completed the processing sequence for the data in columns 13-25 and resulted in the final data array shown in Table A.9.

Table A.10 shows the engine performance data (columns 26-31) after three-point interpolation was used to provide performance measures for each second during the run. Columns 26 and 29 were then added to obtain the total shaft horsepower given in column 32. Port and starboard shaft and engine RPM data (columns 27 and 30, 28 and 31, respectively) were averaged and placed in columns 33 and 34.

Table A.10 also shows water depth at the stern and bow for each second of the run (columns 37 and 38) derived from three-point

interpolation of the limited depth data provided at the start of the processing (Table A.4, columns 37 and 38). Current velocities at the bow of the tow are listed in columns 35 and 36 of Table A.10 relative to the X and Y axes. This allows tow speed through the water in feet/second to be calculated at each second of the run by:

$$V_{water} = [(\text{Col } 16 - \text{Col. } 35)^2 + (\text{Col. } 17 - \text{Col. } 36)^2]^{\frac{1}{2}}.$$

The last processing step used three-point interpolation to develop distances between each river bank and each antenna on the tow as shown in Table A.11, columns 39-42. Table A.11 together with Tables A.7, A.9, and A.10 are examples of the final digital records available after the trial data had been processed.

Table A.1 Page One, Initial Data

TIME		TBOAT RANGE,MTRS		BOM RANGE,METERS		ADJ,TB,RNGE,MTRS		ADJ,BU,RNGE,MTRS		TOWBOAT X,Y DATA,FT		BOMUNIT X,Y DATA,FT	
HHMMSS	SECS	TRANS 1	TRANS 2	TRANS 1	TRANS 2	TRANS 1	TRANS 2	TRANS 1	TRANS 2	XXXXXX.XX	YYYYYY.YY	XXXXXX.XX	YYYYYY.YY
219 0	1	1273.0	5443.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
219 1	2	1273.0	5450.0	1083.0	5159.0	.0	.0	.0	.0	.00	.00	.00	.00
219 2	3	1267.0	5474.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
219 3	4	1266.0	5473.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
219 4	5	1265.0	5472.0	.0	5154.0	.0	.0	.0	.0	.00	.00	.00	.00
219 5	6	1265.0	5465.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
219 6	7	1263.0	5464.0	1076.0	5140.0	.0	.0	.0	.0	.00	.00	.00	.00
219 7	8	1259.0	5461.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
219 8	9	1256.0	5456.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
219 9	10	1256.0	5455.0	1071.0	5135.0	.0	.0	.0	.0	.00	.00	.00	.00
21910	11	1254.0	5451.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21911	12	.0	5449.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21912	13	1245.0	5443.0	1066.0	5120.0	.0	.0	.0	.0	.00	.00	.00	.00
21913	14	1245.0	5440.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21914	15	1242.0	5436.0	.0	5122.0	.0	.0	.0	.0	.00	.00	.00	.00
21915	16	1240.0	5435.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21916	17	1239.0	5431.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21917	18	1236.0	5426.0	1054.0	5110.0	.0	.0	.0	.0	.00	.00	.00	.00
21918	19	1231.0	5422.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21919	20	1233.0	5415.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21920	21	1231.0	5416.0	1056.0	5101.0	.0	.0	.0	.0	.00	.00	.00	.00
21921	22	1229.0	5412.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21922	23	1225.0	5410.0	1054.0	5088.0	.0	.0	.0	.0	.00	.00	.00	.00
21923	24	1226.0	5405.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21924	25	1221.0	5402.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21925	26	.0	5402.0	1036.0	5080.0	.0	.0	.0	.0	.00	.00	.00	.00
21926	27	1216.0	5395.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21927	28	1215.0	5391.0	1046.0	5071.0	.0	.0	.0	.0	.00	.00	.00	.00
21928	29	1214.0	5388.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21929	30	1208.0	5384.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21930	31	1208.0	5382.0	1042.0	5062.0	.0	.0	.0	.0	.00	.00	.00	.00
21931	32	1205.0	5379.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21932	33	1203.0	5376.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21933	34	1202.0	5371.0	1041.0	5055.0	.0	.0	.0	.0	.00	.00	.00	.00
21934	35	1202.0	5369.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21935	36	1202.0	5363.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21936	37	1194.0	5364.0	1034.0	5044.0	.0	.0	.0	.0	.00	.00	.00	.00
21937	38	1190.0	5356.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21938	39	1193.0	5356.0	.0	5031.0	.0	.0	.0	.0	.00	.00	.00	.00
21939	40	1195.0	5353.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21940	41	1192.0	5349.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21941	42	1185.0	5342.0	1026.0	5022.0	.0	.0	.0	.0	.00	.00	.00	.00
21942	43	1183.0	5339.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21943	44	1185.0	5338.0	1025.0	5015.0	.0	.0	.0	.0	.00	.00	.00	.00
21944	45	1180.0	5332.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21945	46	1177.0	5328.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21946	47	1176.0	5326.0	.0	5002.0	.0	.0	.0	.0	.00	.00	.00	.00
21947	48	1175.0	5319.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21948	49	1171.0	5320.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21949	50	1175.0	5315.0	1021.0	4996.0	.0	.0	.0	.0	.00	.00	.00	.00
21950	51	1168.0	5311.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21951	52	1171.0	5307.0	1016.0	4988.0	.0	.0	.0	.0	.00	.00	.00	.00
21952	53	1166.0	5336.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21953	54	1164.0	5302.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21954	55	1161.0	5299.0	1010.0	4973.0	.0	.0	.0	.0	.00	.00	.00	.00
21955	56	1157.0	5295.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21956	57	1156.0	5290.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21957	58	1155.0	5297.0	1007.0	4966.0	.0	.0	.0	.0	.00	.00	.00	.00
21958	59	1152.0	5284.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
21959	60	1150.0	5290.0	1003.0	4956.0	.0	.0	.0	.0	.00	.00	.00	.00
220 0	61	1146.0	5276.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
220 1	62	1147.0	5279.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
220 2	63	1141.0	5271.0	1002.0	4947.0	.0	.0	.0	.0	.00	.00	.00	.00
220 3	64	1144.0	5266.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
220 4	65	1140.0	5260.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
220 5	66	1139.0	5256.0	999.0	4937.0	.0	.0	.0	.0	.00	.00	.00	.00
220 6	67	1139.0	5252.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
220 7	68	1134.0	5248.0	988.0	4924.0	.0	.0	.0	.0	.00	.00	.00	.00
220 8	69	1133.0	5242.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
220 9	70	1131.0	5243.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22010	71	1127.0	5239.0	995.0	4918.0	.0	.0	.0	.0	.00	.00	.00	.00
22011	72	1123.0	5236.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22012	73	1124.0	5230.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22013	74	1120.0	5224.0	990.0	4907.0	.0	.0	.0	.0	.00	.00	.00	.00
22014	75	1119.0	5222.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22015	76	1124.0	5220.0	988.0	4896.0	.0	.0	.0	.0	.00	.00	.00	.00
22016	77	1120.0	5216.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22017	78	1116.0	5214.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22018	79	1116.0	5208.0	987.0	4890.0	.0	.0	.0	.0	.00	.00	.00	.00
22019	80	1115.0	5204.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22020	81	1110	5202.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22021	82	1108.0	5198.0	986.0	4880.0	.0	.0	.0	.0	.00	.00	.00	.00
22022	83	1105.0	5194.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22023	84	1103.0	5191.0	984.0	4868.0	.0	.0	.0	.0	.00	.00	.00	.00
22024	85	1099.0	5188.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22025	86	1100.0	5185.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22026	87	1096.0	5178.0	.0	4860.0	.0	.0	.0	.0	.00	.00	.00	.00
22027	88	1100.0	5173.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22028	89	1098.0	5169.0	980.0	4849.0	.0	.0	.0	.0	.00	.00	.00	.00
22029	90	1094.0	5168.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22030	91	1092.0	5164.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22031	92	1092.0	5162.0	978.0	4836.0	.0	.0	.0	.0	.00	.00	.00	.00
22032	93	1087.0	5154.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22033	94	1083.0	5154.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22034	95	1085.0	5150.0	977.0	4830.0	.0	.0	.0	.0	.00	.00	.00	.00
22035	96	1082.0	5149.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22036	97	1074.0	5139.0	973.0	4819.0	.0	.0	.0	.0	.00	.00	.00	.00
22037	98	1078.0	5136.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22038	99	1080.0	5132.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22039	100	1077.0	5130.0	971.0	4805.0	.0	.0	.0	.0	.00	.00	.00	.00
22040	101	1072.0	5124.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22041	102	1067.0	5120.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22042	103	1070.0	5115.0	976.0	4795.0	.0	.0	.0	.0	.00	.00	.00	.00
22043	104	1069.0	5111.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22044	105	1072.0	5109.0	.0	.0	.0	.0	.0	.0	.00	.00	.00	.00
22045	106	1066.0	5104.0	967.0	4788.0	.0	.0	.0	.0	.00	.00	.00	.00
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

Table A.2 Page Two, Initial Data

·	TIME	LCG/LCG X,Y DATA,FT		HEADING	LCG VELOCITY,FEET/SEC.			YAW RATE	CRFT ANG	LCG ACCELERATION,FT/SEC2			YAW ACC,	RUDDR
HHMMSS	SECS	XXXXXX.XX	YYYYYY.YY	DEGREES	D(X)/DT	D(Y)/DT	D(U)/DT	DEG./SEC	DEGREES	D2X/DT2	D2Y/DT2	D2U/DT2	DEG/SEC2	DEGR.
219 0	1	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 1	2	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 2	3	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 3	4	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 4	5	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 5	6	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 6	7	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 7	8	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 8	9	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
219 9	10	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21910	11	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21911	12	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21912	13	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21913	14	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21914	15	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21915	16	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21916	17	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21917	18	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21918	19	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	3.4
21919	20	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21920	21	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21921	22	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21922	23	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21923	24	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21924	25	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21925	26	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21926	27	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21927	28	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21928	29	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21929	30	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21930	31	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21931	32	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21932	33	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21933	34	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21934	35	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21935	36	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21936	37	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21937	38	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21938	39	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21939	40	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21940	41	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21941	42	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21942	43	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21943	44	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21944	45	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21945	46	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21946	47	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21947	48	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
21948	49	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21949	50	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21950	51	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21951	52	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21952	53	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21953	54	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21954	55	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21955	56	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21956	57	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21957	58	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21958	59	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
21959	60	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
220 0	61	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
220 1	62	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	2.5
220 2	63	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	4.1
220 3	64	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
220 4	65	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
220 5	66	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
220 6	67	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
220 7	68	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
220 8	69	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
220 9	70	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22010	71	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22011	72	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22012	73	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22013	74	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22014	75	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22015	76	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22016	77	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	5.3
22017	78	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	4.9
22018	79	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22019	80	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22020	81	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22021	82	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22022	83	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22023	84	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22024	85	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22025	86	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22026	87	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22027	88	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22028	89	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22029	90	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22030	91	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22031	92	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22032	93	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22033	94	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22034	95	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22035	96	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22036	97	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22037	98	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22038	99	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22039	100	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22040	101	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22041	102	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22042	103	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22043	104	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22044	105	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
22045	106	.00	.00	.000	.000	.000	.000	.00000	.000	.00000	.00000	.00000	.00000	.0
		(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)

Table A.3 Page Three, Initial Data

TIME HHMMSS	SECS	STARBOARD ENGINE HP	SRPM	ERPM	PORT ENGINE HP	SRPM	ERPM	BOTH ENGINES HP	SRPM	ERPM	CURRENT X,FT/SC	Y,FT/SC	DEPTH,FT STERN	BOW
219 0	1	1571.10	220.04	765.40	1869.54	230.00	798.10	.00	.00	.00	.000	.000	.0	.0
219 1	2	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 2	3	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 3	4	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 4	5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 5	6	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 6	7	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 7	8	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 8	9	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
219 9	10	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21910	11	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21911	12	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21912	13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21913	14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21914	15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21915	16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21916	17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21917	18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21918	19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21919	20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21920	21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21921	22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21922	23	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21923	24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21924	25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21925	26	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21926	27	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21927	28	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21928	29	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21929	30	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21930	31	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21931	32	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21932	33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21933	34	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21934	35	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21935	36	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21936	37	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21937	38	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21938	39	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21939	40	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21940	41	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	32.0	32.0
21941	42	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21942	43	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21943	44	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21944	45	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21945	46	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21946	47	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21947	48	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21948	49	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21949	50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21950	51	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21951	52	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21952	53	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21953	54	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21954	55	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21955	56	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21956	57	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21957	58	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21958	59	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
21959	60	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 0	61	1543.30	221.00	766.87	1882.20	230.00	798.10	.00	.00	.00	.000	.000	32.0	30.0
220 1	62	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 2	63	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 3	64	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 4	65	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 5	66	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 6	67	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 7	68	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 8	69	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
220 9	70	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22010	71	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22011	72	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22012	73	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22013	74	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22014	75	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22015	76	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22016	77	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22017	78	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22018	79	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22019	80	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22020	81	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22021	82	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22022	83	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22023	84	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22024	85	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22025	86	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22026	87	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22027	88	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22028	89	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22029	90	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22030	91	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22031	92	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22032	93	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22033	94	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22034	95	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22035	96	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22036	97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22037	98	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22038	99	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22039	100	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22040	101	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22041	102	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22042	103	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22043	104	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22044	105	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
22045	106	.00	.00	.00	.00	.00	.00	.00	.00	.00	.000	.000	.0	.0
		(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)

Table A.4 Page Four, Initial Data

TIME HHMMSS	TIME SECS	P.W. DIST N/S BANK	OFF,FT. E/W BANK	BOW DIST. N/S BANK	OFF,FT. E/W BANK
219 0	1	.00	.00	.00	.00
219 1	2	.00	.00	.00	.00
219 2	3	.00	.00	.00	.00
219 3	4	.00	.00	.00	.00
219 4	5	.00	.00	.00	.00
219 5	6	.00	.00	.00	.00
219 6	7	.00	.00	.00	.00
219 7	8	.00	.00	.00	.00
219 8	9	.00	.00	.00	.00
219 9	10	.00	.00	.00	.00
21910	11	.00	.00	.00	.00
21911	12	.00	.00	.00	.00
21912	13	.00	.00	.00	.00
21913	14	.00	.00	.00	.00
21914	15	.00	.00	.00	.00
21915	16	.00	.00	.00	.00
21916	17	.00	.00	.00	.00
21917	18	.00	.00	.00	.00
21918	19	.00	.00	.00	.00
21919	20	.00	.00	.00	.00
21920	21	.00	.00	.00	.00
21921	22	.00	.00	.00	.00
21922	23	.00	.00	.00	.00
21923	24	.00	.00	.00	.00
21924	25	.00	.00	.00	.00
21925	26	.00	.00	.00	.00
21926	27	.00	.00	.00	.00
21927	28	.00	.00	.00	.00
21928	29	.00	.00	.00	.00
21929	30	.00	.00	.00	.00
21930	31	.00	.00	.00	.00
21931	32	.00	.00	.00	.00
21932	33	.00	.00	.00	.00
21933	34	.00	.00	.00	.00
21934	35	.00	.00	.00	.00
21935	36	.00	.00	.00	.00
21936	37	.00	.00	.00	.00
21937	38	.00	.00	.00	.00
21938	39	.00	.00	.00	.00
21939	40	.00	.00	.00	.00
21940	41	1100.00	1767.00	1150.00	1767.00
21941	42	.00	.00	.00	.00
21942	43	.00	.00	.00	.00
21943	44	.00	.00	.00	.00
21944	45	.00	.00	.00	.00
21945	46	.00	.00	.00	.00
21946	47	.00	.00	.00	.00
21947	48	.00	.00	.00	.00
21948	49	.00	.00	.00	.00
21949	50	.00	.00	.00	.00
21950	51	.00	.00	.00	.00
21951	52	.00	.00	.00	.00
21952	53	.00	.00	.00	.00
21953	54	.00	.00	.00	.00
21954	55	.00	.00	.00	.00
21955	56	.00	.00	.00	.00
21956	57	.00	.00	.00	.00
21957	58	.00	.00	.00	.00
21958	59	.00	.00	.00	.00
21959	60	.00	.00	.00	.00
220 0	61	1077.00	1793.00	1117.00	1700.00
220 1	62	.00	.00	.00	.00
220 2	63	.00	.00	.00	.00
220 3	64	.00	.00	.00	.00
220 4	65	.00	.00	.00	.00
220 5	66	.00	.00	.00	.00
220 6	67	.00	.00	.00	.00
220 7	68	.00	.00	.00	.00
220 8	69	.00	.00	.00	.00
220 9	70	.00	.00	.00	.00
22010	71	.00	.00	.00	.00
22011	72	.00	.00	.00	.00
22012	73	.00	.00	.00	.00
22013	74	.00	.00	.00	.00
22014	75	.00	.00	.00	.00
22015	76	.00	.00	.00	.00
22016	77	.00	.00	.00	.00
22017	78	.00	.00	.00	.00
22018	79	.00	.00	.00	.00
22019	80	.00	.00	.00	.00
22020	81	.00	.00	.00	.00
22021	82	.00	.00	.00	.00
22022	83	.00	.00	.00	.00
22023	84	.00	.00	.00	.00
22024	85	.00	.00	.00	.00
22025	86	.00	.00	.00	.00
22026	87	.00	.00	.00	.00
22027	88	.00	.00	.00	.00
22028	89	.00	.00	.00	.00
22029	90	.00	.00	.00	.00
22030	91	.00	.00	.00	.00
22031	92	.00	.00	.00	.00
22032	93	.00	.00	.00	.00
22033	94	.00	.00	.00	.00
22034	95	.00	.00	.00	.00
22035	96	.00	.00	.00	.00
22036	97	.00	.00	.00	.00
22037	98	.00	.00	.00	.00
22038	99	.00	.00	.00	.00
22039	100	.00	.00	.00	.00
22040	101	.00	.00	.00	.00
22041	102	.00	.00	.00	.00
22042	103	.00	.00	.00	.00
22043	104	.00	.00	.00	.00
22044	105	.00	.00	.00	.00
22045	106	.00	.00	.00	.00
		(39)	(40)	(41)	(42)

Table A.5 Page One, Adjusted Range Data

HHMMSS	TIME SECS	TBOAT RANGE,MTRS TRANS 1	TRANS 2	BOW RANGE,METERS TRANS 1	TRANS 2	ADJ.TB.RNGE,MTRS TRANS 1	TRANS 2	ADJ.BW.RNGE,MTRS TRANS 1	TRANS 2	TOWBOAT X,Y DATA,FT XXXXXX.XX	YYYYYY.YY	BOWUNIT X,Y DATA,FT XXXXXX.XX	YYYYYY.YY
219 0	1	1273.0	5443.0	.0	.0	1266.5	.0	.0	.0	.00	.00	.00	.00
219 1	2	1270.0	5480.0	1085.0	5139.0	1265.5	.0	.0	.0	.00	.00	.00	.00
219 2	3	1267.0	5474.0	.0	.0	1262.5	.0	.0	.0	.00	.00	.00	.00
219 3	4	1266.0	5473.0	.0	.0	1261.5	.0	1077.7	5139.0	.00	.00	.00	.00
219 4	5	1265.0	5472.0	.0	5154.0	1260.5	.0	.0	.0	.00	.00	.00	.00
219 5	6	1263.0	5465.0	.0	.0	1260.5	.0	.0	.0	.00	.00	.00	.00
219 6	7	1260.0	5464.0	1076.0	5140.0	1255.5	.0	.0	5154.0	.00	.00	.00	.00
219 7	8	1259.0	5461.0	.0	.0	1254.5	.0	.0	.0	.00	.00	.00	.00
219 8	9	1256.0	5456.0	.0	.0	1251.5	.0	1070.7	5140.0	.00	.00	.00	.00
219 9	10	1256.0	5455.0	1071.0	5135.0	1251.5	.0	.0	.0	.00	.00	.00	.00
21910	11	1254.0	5451.0	.0	.0	1249.5	.0	.0	.0	.00	.00	.00	.00
21911	12	.0	5449.0	.0	.0	.0	.0	1065.7	5135.0	.00	.00	.00	.00
21912	13	1249.0	5443.0	1068.0	5126.0	1243.4	.0	.0	.0	.00	.00	.00	.00
21913	14	1245.0	5440.0	.0	.0	1240.4	.0	.0	.0	.00	.00	.00	.00
21914	15	1242.0	5436.0	.0	5122.0	1237.4	.0	1062.7	5126.0	.00	.00	.00	.00
21915	16	1240.0	5435.0	.0	.0	1235.4	.0	.0	.0	.00	.00	.00	.00
21916	17	1238.0	5431.0	.0	.0	1233.4	.0	.0	5122.0	.00	.00	.00	.00
21917	18	1236.0	5426.0	1059.0	5110.0	1231.4	.0	.0	.0	.00	.00	.00	.00
21918	19	1231.0	5422.0	.0	.0	1226.4	.0	.0	.0	.00	.00	.00	.00
21919	20	1233.0	5418.0	.0	.0	1228.4	.0	1055.6	5110.0	.00	.00	.00	.00
21920	21	1231.0	5416.0	1056.0	5101.0	1226.4	.0	.0	.0	.00	.00	.00	.00
21921	22	1226.0	5412.0	.0	.0	1221.3	.0	.0	.0	.00	.00	.00	.00
21922	23	1225.0	5410.0	1058.0	5098.0	1220.3	.0	1050.6	5101.0	.00	.00	.00	.00
21923	24	1224.0	5405.0	.0	.0	1221.3	.0	.0	.0	.00	.00	.00	.00
21924	25	1221.0	5402.0	.0	.0	1216.3	.0	1048.6	5088.0	.00	.00	.00	.00
21925	26	.0	5402.0	1058.0	5080.0	.0	.0	.0	.0	.00	.00	.00	.00
21926	27	1216.0	5396.0	.0	.0	1211.3	.0	.0	.0	.00	.00	.00	.00
21927	28	1215.0	5391.0	1046.0	5071.0	1210.3	.0	1048.6	5080.0	.00	.00	.00	.00
21928	29	1214.0	5388.0	.0	.0	1209.3	.0	.0	.0	.00	.00	.00	.00
21929	30	1208.0	5386.0	.0	.0	1203.3	.0	1040.5	5071.0	.00	.00	.00	.00
21930	31	1208.0	5382.0	1042.0	5062.0	1203.3	.0	.0	.0	.00	.00	.00	.00
21931	32	1205.0	5379.0	.0	.0	1200.3	.0	.0	.0	.00	.00	.00	.00
21932	33	1203.0	5376.0	.0	.0	1198.3	.0	1036.5	5062.0	.00	.00	.00	.00
21933	34	1202.0	5371.0	1041.0	5055.0	1197.3	.0	.0	.0	.00	.00	.00	.00
21934	35	1202.0	5369.0	.0	.0	1197.3	.0	.0	.0	.00	.00	.00	.00
21935	36	1202.0	5363.0	.0	.0	1197.3	.0	1035.5	5055.0	.00	.00	.00	.00
21936	37	1194.0	5364.0	1036.0	5044.0	1189.2	.0	.0	.0	.00	.00	.00	.00
21937	38	1194.0	5356.0	.0	.0	1189.2	.0	.0	.0	.00	.00	.00	.00
21938	39	1193.0	5356.0	.0	5031.0	1188.2	.0	1028.5	5044.0	.00	.00	.00	.00
21939	40	1195.0	5353.0	.0	.0	1190.2	.0	.0	.0	.00	.00	.00	.00
21940	41	1192.0	5348.0	.0	.0	1187.2	.0	.0	5031.0	.00	.00	.00	.00
21941	42	1185.0	5342.0	1026.0	5022.0	1180.2	.0	.0	.0	.00	.00	.00	.00
21942	43	1183.0	5339.0	.0	.0	1178.2	.0	.0	.0	.00	.00	.00	.00
21943	44	1185.0	5338.0	1025.0	5015.0	1180.2	.0	1020.6	5022.0	.00	.00	.00	.00
21944	45	1180.0	5332.0	.0	.0	1175.2	.0	.0	.0	.00	.00	.00	.00
21945	46	1177.0	5328.0	.0	.0	1172.2	.0	1019.6	5015.0	.00	.00	.00	.00
21946	47	1176.0	5326.0	.0	5002.0	1171.2	.0	.0	.0	.00	.00	.00	.00
21947	48	1175.0	5319.0	.0	.0	1170.1	.0	.0	.0	.00	.00	.00	.00
21948	49	1171.0	5320.0	.0	.0	1166.1	.0	.0	5002.0	.00	.00	.00	.00
21949	50	1178.0	5315.0	1021.0	4996.0	1173.2	.0	.0	.0	.00	.00	.00	.00
21950	51	1168.0	5311.0	.0	.0	1163.1	.0	.0	.0	.00	.00	.00	.00
21951	52	1171.0	5307.0	1016.0	4988.0	1166.1	.0	1015.6	4996.0	.00	.00	.00	.00
21952	53	1166.0	5306.0	.0	.0	1161.1	.0	.0	.0	.00	.00	.00	.00
21953	54	1164.0	5302.0	.0	.0	1159.1	.0	1010.6	4988.0	.00	.00	.00	.00
21954	55	1161.0	5298.0	1010.0	4973.0	1156.1	.0	.0	.0	.00	.00	.00	.00
21955	56	1157.0	5295.0	.0	.0	1152.1	.0	.0	.0	.00	.00	.00	.00
21956	57	1156.0	5290.0	.0	.0	1151.1	.0	1004.6	4973.0	.00	.00	.00	.00
21957	58	1155.0	5287.0	1007.0	4968.0	1150.1	.0	.0	.0	.00	.00	.00	.00
21958	59	1152.0	5284.0	.0	.0	1147.0	.0	.0	.0	.00	.00	.00	.00
21959	60	1150.0	5280.0	1003.0	4956.0	1145.0	.0	1001.3	4968.0	.00	.00	.00	.00
220 0	61	1146.0	5276.0	.0	.0	1141.0	.0	.0	.0	.00	.00	.00	.00
220 1	62	1147.0	5275.0	.0	.0	1142.0	.0	997.3	4956.0	.00	.00	.00	.00
220 2	63	1141.0	5271.0	1002.0	4947.0	1136.0	.0	.0	.0	.00	.00	.00	.00
220 3	64	1144.0	5264.0	.0	.0	1139.0	.0	.0	.0	.00	.00	.00	.00
220 4	65	1140.0	5260.0	.0	.0	1135.0	.0	996.3	4947.0	.00	.00	.00	.00
220 5	66	1139.0	5256.0	999.0	4937.0	1134.0	.0	.0	.0	.00	.00	.00	.00
220 6	67	1139.0	5252.0	.0	.0	1134.0	.0	.0	.0	.00	.00	.00	.00
220 7	68	1134.0	5248.0	988.0	4924.0	1129.0	.0	993.3	4937.0	.00	.00	.00	.00
220 8	69	1133.0	5242.0	.0	.0	1128.0	.0	.0	.0	.00	.00	.00	.00
220 9	70	1131.0	5243.0	.0	.0	1126.0	.0	982.2	4924.0	.00	.00	.00	.00
22010	71	1127.0	5239.0	995.0	4918.0	1121.9	.0	.0	.0	.00	.00	.00	.00
22011	72	1123.0	5236.0	.0	.0	1117.9	.0	.0	.0	.00	.00	.00	.00
22012	73	1126.0	5230.0	.0	.0	1120.9	.0	989.3	4918.0	.00	.00	.00	.00
22013	74	1120.0	5224.0	998.0	4907.0	1114.9	.0	.0	.0	.00	.00	.00	.00
22014	75	1119.0	5222.0	.0	.0	1113.9	.0	.0	.0	.00	.00	.00	.00
22015	76	1124.0	5223.0	988.0	4896.0	1118.9	.0	988.3	4907.0	.00	.00	.00	.00
22016	77	1120.0	5216.0	.0	.0	1114.9	.0	.0	.0	.00	.00	.00	.00
22017	78	1118.0	5214.0	.0	.0	1112.9	.0	982.2	4896.0	.00	.00	.00	.00
22018	79	1116.0	5208.0	987.0	4890.0	1110.9	.0	.0	.0	.00	.00	.00	.00
22019	80	1115.0	5204.0	.0	.0	1109.9	.0	.0	.0	.00	.00	.00	.00
22020	81	1110.0	5202.0	.0	.0	1104.9	.0	981.2	4890.0	.00	.00	.00	.00
22021	82	1108.0	5198.0	986.0	4880.0	1102.9	.0	.0	.0	.00	.00	.00	.00
22022	83	1105.0	5194.0	.0	.0	1099.9	.0	.0	.0	.00	.00	.00	.00
22023	84	1103.0	5191.0	984.0	4866.0	1097.8	.0	980.2	4880.0	.00	.00	.00	.00
22024	85	1099.0	5188.0	.0	.0	1093.8	.0	.0	.0	.00	.00	.00	.00
22025	86	1100.0	5185.0	.0	.0	1094.8	.0	978.2	4866.0	.00	.00	.00	.00
22026	87	1096.0	5178.0	.0	4860.0	1090.8	.0	.0	.0	.00	.00	.00	.00
22027	88	1100.0	5173.0	.0	.0	1094.8	.0	.0	.0	.00	.00	.00	.00
22028	89	1098.0	5169.0	980.0	4849.0	1092.8	.0	.0	4860.0	.00	.00	.00	.00
22029	90	1094.0	5168.0	.0	.0	1088.8	.0	.0	.0	.00	.00	.00	.00
22030	91	1092.0	5166.0	.0	.0	1086.8	.0	978.2	4849.0	.00	.00	.00	.00
22031	92	1092.0	5160.0	978.0	4836.0	1086.8	.0	.0	.0	.00	.00	.00	.00
22032	93	1087.0	5154.0	.0	.0	1081.8	.0	.0	.0	.00	.00	.00	.00
22033	94	1083.0	5154.0	.0	.0	1077.7	.0	972.2	4836.0	.00	.00	.00	.00
22034	95	1085.0	5150.0	977.0	4830.0	1079.7	.0	.0	.0	.00	.00	.00	.00
22035	96	1082.0	5145.0	.0	.0	1076.7	.0	.0	.0	.00	.00	.00	.00
22036	97	1078.0	5139.0	975.0	4819.0	1072.7	.0	971.2	4830.0	.00	.00	.00	.00
22037	98	1078.0	5136.0	.0	.0	1072.7	.0	.0	.0	.00	.00	.00	.00
22038	99	1080.0	5132.0	.0	.0	1074.7	.0	967.1	4819.0	.00	.00	.00	.00
22039	100	1077.0	5133.0	971.0	4805.0	1071.7	.0	.0	.0	.00	.00	.00	.00
22040	101	1072.0	5124.0	.0	.0	1066.7	.0	.0	.0	.00	.00	.00	.00
22041	102	1067.0	5120.0	.0	.0	1061.7	.0	969.1	4805.0	.00	.00	.00	.00
22042	103	1070.0	5115.0	970.0	4793.0	1064.7	.0	.0	.0	.00	.00	.00	.00
22043	104	1069.0	5111.0	.0	.0	1063.7	.0	.0	.0	.00	.00	.00	.00
22044	105	1072.0	5109.0	.0	.0	1066.7	.0	966.1	4793.0	.00	.00	.00	.00
22045	106	1066.0	5105.0	967.0	4788.0	1060.6	.0	.0	.0	.00	.00	.00	.00
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

Table A.6 Page One, Smoothed Range Data

TIME		TBOAT RANGE,MTRS		BOM RANGE,METERS		ADJ,TB,RNGE,MTRS		ADJ,BM,RNGE,MTRS		TOWBOAT X,Y DATA,FT		BOMUNIT X,Y DATA,FT	
HHMMSS	SECS	TRANS 1	TRANS 2	TRANS 1	TRANS 2	TRANS 1	TRANS 2	TRANS 1	TRANS 2	XXXXXX.XX	YYYYYY.YY	XXXXXX.XX	YYYYYY.YY
219 0	1	1273.0	5483.0	.0	.0	1267.2	5483.1	1082.6	5169.0	.00	.00	.00	.00
219 1	2	1270.0	5480.0	1083.0	5159.0	1265.6	5480.0	1081.0	5165.8	.00	.00	.00	.00
219 2	3	1267.0	5478.0	.0	.0	1264.0	5476.9	1079.5	5162.7	.00	.00	.00	.00
219 3	4	1264.0	5473.0	.0	.0	1262.3	5473.7	1077.9	5159.6	.00	.00	.00	.00
219 4	5	1265.0	5472.0	.0	5150.0	1260.5	5470.6	1076.4	5156.5	.00	.00	.00	.00
219 5	6	1265.0	5465.0	.0	.0	1258.7	5467.3	1074.9	5153.4	.00	.00	.00	.00
219 6	7	1260.0	5464.0	1076.0	5140.0	1256.7	5464.1	1073.4	5150.3	.00	.00	.00	.00
219 7	8	1259.0	5461.0	.0	.0	1254.7	5460.7	1071.9	5147.2	.00	.00	.00	.00
219 8	9	1256.0	5456.0	.0	.0	1252.7	5457.2	1070.4	5144.1	.00	.00	.00	.00
219 9	10	1256.0	5455.0	1071.0	5135.0	1250.5	5453.9	1068.9	5141.1	.00	.00	.00	.00
21910	11	1254.0	5451.0	.0	.0	1248.3	5450.8	1067.5	5138.0	.00	.00	.00	.00
21911	12	.0	5449.0	.0	.0	1245.9	5447.6	1066.0	5135.0	.00	.00	.00	.00
21912	13	1248.0	5443.0	1068.0	5126.0	1243.1	5444.3	1064.6	5132.0	.00	.00	.00	.00
21913	14	1245.0	5440.0	.0	.0	1240.5	5440.6	1063.1	5129.0	.00	.00	.00	.00
21914	15	1242.0	5436.0	.0	5122.0	1238.4	5437.1	1061.7	5125.8	.00	.00	.00	.00
21915	16	1240.0	5435.0	.0	.0	1235.8	5433.4	1060.3	5122.7	.00	.00	.00	.00
21916	17	1238.0	5431.0	.0	.0	1233.3	5429.8	1058.9	5121.4	.00	.00	.00	.00
21917	18	1236.0	5426.0	1054.0	5110.0	1230.9	5426.2	1057.5	5118.1	.00	.00	.00	.00
21918	19	1231.0	5422.0	.0	.0	1229.0	5422.4	1056.1	5114.6	.00	.00	.00	.00
21919	20	1233.0	5418.0	.0	.0	1227.0	5419.2	1054.2	5110.3	.00	.00	.00	.00
21920	21	1231.0	5416.0	1056.0	5101.0	1224.9	5415.9	1053.1	5106.8	.00	.00	.00	.00
21921	22	1226.0	5412.0	.0	.0	1223.1	5412.6	1052.1	5103.1	.00	.00	.00	.00
21922	23	1225.0	5410.0	1058.0	5088.0	1221.0	5409.0	1051.1	5099.0	.00	.00	.00	.00
21923	24	1226.0	5405.0	.0	.0	1218.9	5405.7	1049.9	5095.2	.00	.00	.00	.00
21924	25	1221.0	5402.0	.0	.0	1216.6	5402.5	1048.8	5090.5	.00	.00	.00	.00
21925	26	.0	5402.0	1058.0	5080.0	1214.6	5399.2	1047.8	5086.7	.00	.00	.00	.00
21926	27	1216.0	5396.0	.0	.0	1212.4	5395.9	1046.0	5083.0	.00	.00	.00	.00
21927	28	1215.0	5391.0	1046.0	5071.0	1209.6	5392.6	1045.1	5078.8	.00	.00	.00	.00
21928	29	1214.0	5385.0	.0	.0	1207.2	5389.2	1043.9	5075.3	.00	.00	.00	.00
21929	30	1208.0	5386.0	.0	.0	1205.5	5385.4	1042.6	5071.9	.00	.00	.00	.00
21930	31	1209.0	5382.0	1042.0	5062.0	1203.3	5382.2	1041.3	5068.4	.00	.00	.00	.00
21931	32	1205.0	5379.0	.0	.0	1201.1	5378.5	1039.8	5065.1	.00	.00	.00	.00
21932	33	1203.0	5376.0	.0	.0	1199.1	5374.6	1038.2	5063.3	.00	.00	.00	.00
21933	34	1202.0	5371.0	1041.0	5055.0	1197.2	5371.8	1036.7	5060.1	.00	.00	.00	.00
21934	35	1202.0	5369.0	.0	.0	1195.4	5368.0	1035.2	5056.8	.00	.00	.00	.00
21935	36	1202.0	5363.0	.0	.0	1194.3	5365.4	1033.0	5053.1	.00	.00	.00	.00
21936	37	1194.0	5364.0	1034.0	5044.0	1192.8	5361.6	1031.5	5049.4	.00	.00	.00	.00
21937	38	1190.0	5356.0	.0	.0	1190.8	5358.2	1029.9	5045.7	.00	.00	.00	.00
21938	39	1193.0	5356.0	.0	5031.0	1189.1	5354.8	1028.6	5042.3	.00	.00	.00	.00
21939	40	1195.0	5353.0	.0	.0	1186.9	5351.1	1027.1	5038.5	.00	.00	.00	.00
21940	41	1192.0	5348.0	.0	.0	1184.6	5347.7	1025.9	5034.3	.00	.00	.00	.00
21941	42	1185.0	5342.0	1026.0	5022.0	1182.4	5343.7	1024.6	5030.6	.00	.00	.00	.00
21942	43	1183.0	5339.0	.0	.0	1179.6	5340.0	1023.5	5026.5	.00	.00	.00	.00
21943	44	1185.0	5338.0	1025.0	5015.0	1176.2	5336.1	1022.0	5021.3	.00	.00	.00	.00
21944	45	1180.0	5332.0	.0	.0	1175.7	5332.6	1020.8	5017.3	.00	.00	.00	.00
21945	46	1177.0	5328.0	.0	.0	1173.7	5328.5	1019.7	5013.8	.00	.00	.00	.00
21946	47	1176.0	5326.0	.0	5002.0	1171.7	5324.9	1018.4	5010.2	.00	.00	.00	.00
21947	48	1175.0	5319.0	.0	.0	1170.4	5321.6	1017.1	5006.8	.00	.00	.00	.00
21948	49	1171.0	5320.0	.0	.0	1169.2	5318.3	1015.8	5004.9	.00	.00	.00	.00
21949	50	1178.0	5315.0	1021.0	4996.0	1167.4	5314.9	1014.6	5001.3	.00	.00	.00	.00
21950	51	1168.0	5311.0	.0	.0	1165.2	5311.6	1013.3	4997.7	.00	.00	.00	.00
21951	52	1171.0	5307.0	1016.0	4988.0	1163.5	5308.8	1012.6	4993.5	.00	.00	.00	.00
21952	53	1166.0	5306.0	.0	.0	1161.4	5304.9	1011.4	4990.1	.00	.00	.00	.00
21953	54	1164.0	5302.0	.0	.0	1159.2	5301.4	1010.9	4987.0	.00	.00	.00	.00
21954	55	1161.0	5298.0	1010.0	4973.0	1156.5	5298.0	1009.4	4983.4	.00	.00	.00	.00
21955	56	1157.0	5295.0	.0	.0	1154.2	5294.2	1007.9	4979.8	.00	.00	.00	.00
21956	57	1156.0	5290.0	.0	.0	1151.0	5290.9	1005.9	4976.4	.00	.00	.00	.00
21957	58	1155.0	5287.0	1007.0	4964.0	1149.1	5287.7	1004.5	4972.8	.00	.00	.00	.00
21958	59	1152.0	5284.0	.0	.0	1146.5	5284.3	1003.2	4969.2	.00	.00	.00	.00
21959	60	1150.0	5280.0	1003.0	4956.0	1144.4	5280.5	1000.5	4964.6	.00	.00	.00	.00
220 0	61	1148.0	5276.0	.0	.0	1142.6	5276.9	999.2	4960.9	.00	.00	.00	.00
220 1	62	1147.0	5275.0	.0	.0	1140.8	5273.3	999.2	4958.0	.00	.00	.00	.00
220 2	63	1141.0	5271.0	1002.0	4947.0	1139.1	5269.1	997.7	4954.2	.00	.00	.00	.00
220 3	64	1144.0	5266.0	.0	.0	1137.3	5265.0	996.1	4950.4	.00	.00	.00	.00
220 4	65	1140.0	5260.0	.0	.0	1135.7	5260.7	994.8	4946.7	.00	.00	.00	.00
220 5	66	1139.0	5256.0	990.0	4937.0	1133.6	5256.8	993.0	4943.0	.00	.00	.00	.00
220 6	67	1139.0	5252.0	.0	.0	1131.8	5253.0	991.9	4939.3	.00	.00	.00	.00
220 7	68	1134.0	5249.0	988.0	4924.0	1129.8	5248.9	990.2	4934.5	.00	.00	.00	.00
220 8	69	1133.0	5242.0	.0	.0	1127.0	5244.7	989.8	4930.8	.00	.00	.00	.00
220 9	70	1131.0	5243.0	.0	.0	1125.0	5240.9	989.1	4928.0	.00	.00	.00	.00
22010	71	1127.0	5239.0	999.0	4918.0	1122.6	5237.2	988.3	4924.3	.00	.00	.00	.00
22011	72	1123.0	5236.0	.0	.0	1120.9	5233.9	987.5	4920.5	.00	.00	.00	.00
22012	73	1126.0	5230.0	.0	.0	1119.0	5230.4	986.7	4916.0	.00	.00	.00	.00
22013	74	1120.0	5224.0	996.0	4907.0	1117.7	5226.7	985.9	4912.4	.00	.00	.00	.00
22014	75	1119.0	5222.0	.0	.0	1116.5	5223.1	985.2	4908.9	.00	.00	.00	.00
22015	76	1124.0	5220.0	988.0	4896.0	1115.2	5219.5	985.2	4905.3	.00	.00	.00	.00
22016	77	1120.0	5216.0	.0	.0	1113.8	5215.5	986.6	4901.9	.00	.00	.00	.00
22017	78	1118.0	5214.0	.0	.0	1112.5	5211.9	985.1	4899.7	.00	.00	.00	.00
22018	79	1116.0	5208.0	987.0	4890.0	1110.5	5208.4	984.6	4896.2	.00	.00	.00	.00
22019	80	1115.0	5204.0	.0	.0	1108.2	5205.3	983.9	4892.6	.00	.00	.00	.00
22020	81	1110.0	5202.0	.0	.0	1105.7	5202.1	981.7	4888.3	.00	.00	.00	.00
22021	82	1108.0	5198.0	986.0	4880.0	1102.9	5198.0	980.9	4884.7	.00	.00	.00	.00
22022	83	1105.0	5194.0	.0	.0	1100.2	5194.4	980.1	4881.1	.00	.00	.00	.00
22023	84	1103.0	5191.0	984.0	4868.0	1098.3	5190.3	979.3	4878.1	.00	.00	.00	.00
22024	85	1099.0	5188.0	.0	.0	1096.3	5186.5	978.5	4874.3	.00	.00	.00	.00
22025	86	1100.0	5185.0	.0	.0	1094.8	5183.1	978.1	4871.0	.00	.00	.00	.00
22026	87	1096.0	5175.0	.0	4860.0	1093.6	5179.0	977.5	4867.1	.00	.00	.00	.00
22027	88	1100.0	5173.0	.0	.0	1091.9	5174.9	976.9	4863.0	.00	.00	.00	.00
22028	89	1098.0	5169.0	980.0	4849.0	1090.3	5171.2	976.2	4857.5	.00	.00	.00	.00
22029	90	1094.0	5168.0	.0	.0	1088.9	5167.5	975.5	4853.6	.00	.00	.00	.00
22030	91	1092.0	5164.0	.0	.0	1087.1	5163.7	974.8	4849.6	.00	.00	.00	.00
22031	92	1092.0	5160.0	978.0	4836.0	1084.9	5159.9	974.0	4845.7	.00	.00	.00	.00
22032	93	1087.0	5154.0	.0	.0	1082.6	5156.0	973.2	4841.8	.00	.00	.00	.00
22033	94	1083.0	5158.0	.0	.0	1080.8	5152.6	972.3	4838.9	.00	.00	.00	.00
22034	95	1085.0	5150.0	977.0	4830.0	1078.7	5148.8	971.6	4835.0	.00	.00	.00	.00
22035	96	1082.0	5149.0	.0	.0	1076.7	5144.9	970.6	4831.0	.00	.00	.00	.00
22036	97	1078.0	5139.0	973.0	4819.0	1074.7	5140.6	969.7	4826.6	.00	.00	.00	.00
22037	98	1074.0	5134.0	.0	.0	1072.5	5136.3	969.0	4822.6	.00	.00	.00	.00
22038	99	1080.0	5132.0	.0	.0	1070.9	5132.4	968.2	4818.5	.00	.00	.00	.00
22039	100	1077.0	5130.0	971.0	4805.0	1069.8	5128.6	967.4	4814.8	.00	.00	.00	.00
22040	101	1072.0	5124.0	.0	.0	1068.5	5124.0	966.6	4811.1	.00	.00	.00	.00
22041	102	1067.0	5120.0	.0	.0	1066.0	5119.6	965.6	4807.6	.00	.00	.00	.00
22042	103	1070.0	5115.0	970.0	4795.0	1065.1	5115.7	964.7	4803.6	.00	.00	.00	.00
22043	104	1069.0	5111.0	.0	.0	1063.4	5111.9	964.2	4800.0	.00	.00	.00	.00
22044	105	1072.0	5109.0	.0	.0	1061.6	5107.7	963.6	4796.0	.00	.00	.00	.00
22045	106	1066.0	5104.0	967.0	4786.0	1059.8	5103.4	962.9	4791.9	.00	.00	.00	.00
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

Table A.7 Page One, Smoothed Antenna Coordinates

TIME HHMMSS	SECS	TBOAT RANGE,MTRS TRANS 1	TRANS 2	BOW RANGE,METERS TRANS 1	TRANS 2	ADJ,TR,RNGE,MTRS TRANS 1	TRANS 2	ADJ,BW,RNGE,MTRS TRANS 1	TRANS 2	TOWBOAT X,Y DATA,FT XXXXXX,XX	YYYYYY,YY	BOWUNIT X,Y DATA,FT XXXXXX,XX	YYYYYY,YY
219 0	1	1273.0	5483.0	.0	.0	1267.2	5483.1	1082.6	5169.0	648197,19	42970,65	649232,67	42942,90
219 1	2	1270.0	5480.0	1083.0	5159.0	1265.6	5480.0	1081.0	5165.8	648207,76	42968,39	649242,75	42942,72
219 2	3	1267.0	5478.0	.0	.0	1264.0	5476.9	1079.5	5162.7	648218,34	42966,33	649252,99	42942,53
219 3	4	1266.0	5473.0	.0	.0	1262.3	5473.7	1077.9	5159.6	648228,91	42964,27	649263,26	42942,35
219 4	5	1265.0	5472.0	.0	5154.0	1260.5	5470.6	1076.4	5156.5	648239,55	42962,37	649273,50	42942,16
219 5	6	1265.0	5469.0	.0	.0	1258.7	5467.3	1074.9	5153.4	648250,36	42960,42	649283,71	42941,99
219 6	7	1260.0	5464.0	1076.0	5140.0	1256.7	5464.1	1073.4	5150.3	648261,28	42959,17	649293,88	42941,82
219 7	8	1259.0	5461.0	.0	.0	1254.7	5460.7	1071.9	5147.2	648272,16	42958,13	649304,02	42941,65
219 8	9	1256.0	5456.0	.0	.0	1252.7	5457.2	1070.4	5144.1	648283,09	42957,44	649314,12	42941,49
219 9	10	1256.0	5455.0	1071.0	5135.0	1250.9	5453.9	1068.9	5141.1	648293,85	42957,46	649324,20	42941,34
21910	11	1254.0	5451.0	.0	.0	1248.3	5450.8	1067.5	5138.0	648304,84	42957,78	649334,23	42941,19
21911	12	.0	5449.0	.0	.0	1245.9	5447.4	1066.0	5135.0	648315,94	42958,06	649344,29	42941,01
21912	13	1248.0	5443.0	1068.0	5126.0	1243.1	5444.3	1064.6	5132.0	648327,08	42958,44	649354,37	42940,81
21913	14	1245.0	5440.0	.0	.0	1240.5	5440.6	1063.1	5129.0	648339,34	42959,37	649363,62	42941,04
21914	15	1242.0	5436.0	.0	5122.0	1239.4	5437.1	1061.7	5125.8	648349,83	42960,01	649372,98	42941,20
21915	16	1240.0	5435.0	.0	.0	1235.8	5433.4	1060.3	5122.7	648361,57	42960,21	649382,55	42941,23
21916	17	1239.0	5431.0	.0	.0	1233.3	5429.8	1058.9	5121.4	648373,39	42959,64	649392,71	42941,20
21917	18	1236.0	5426.0	1054.0	5110.0	1230.9	5426.2	1057.5	5118.1	648385,02	42959,30	649403,16	42940,87
21918	19	1231.0	5422.0	.0	.0	1229.0	5422.4	1056.1	5114.6	648396,59	42958,66	649413,90	42940,21
21919	20	1233.0	5418.0	.0	.0	1227.0	5419.2	1054.2	5110.3	648408,14	42957,91	649425,12	42939,09
21920	21	1231.0	5416.0	1056.0	5101.0	1224.9	5415.9	1053.1	5106.8	648419,49	42956,83	649437,53	42937,28
21921	22	1226.0	5412.0	.0	.0	1223.1	5412.6	1052.1	5103.1	648430,69	42955,88	649450,66	42935,00
21922	23	1225.0	5410.0	1054.0	5068.0	1221.0	5409.0	1051.1	5099.0	648441,63	42955,31	649463,92	42932,69
21923	24	1226.0	5405.0	.0	.0	1218.9	5405.7	1049.9	5095.2	648452,59	42954,93	649476,96	42930,28
21924	25	1221.0	5402.0	.0	.0	1216.8	5402.5	1048.8	5090.5	648463,65	42954,92	649490,29	42927,65
21925	26	.0	5402.0	1054.0	5080.0	1214.6	5399.2	1047.4	5086.7	648474,62	42955,39	649503,51	42925,25
21926	27	1216.0	5396.0	.0	.0	1212.4	5395.9	1046.0	5083.0	648485,68	42955,51	649516,42	42923,21
21927	28	1215.0	5391.0	1046.0	5071.0	1209.6	5392.4	1045.1	5078.8	648496,70	42955,79	649529,13	42921,39
21928	29	1214.0	5398.0	.0	.0	1207.2	5388.2	1043.9	5075.3	648507,97	42955,94	649541,16	42920,11
21929	30	1208.0	5386.0	.0	.0	1205.5	5385.4	1042.6	5071.9	648519,41	42955,85	649552,12	42919,52
21930	31	1208.0	5382.0	1042.0	5062.0	1203.3	5382.2	1041.3	5066.4	648530,77	42955,66	649562,92	42919,11
21931	32	1205.0	5379.0	.0	.0	1201.1	5378.5	1039.8	5065.1	648541,94	42954,82	649573,36	42919,25
21932	33	1203.0	5376.0	.0	.0	1199.1	5374.8	1038.2	5063.5	648553,22	42953,36	649583,77	42919,91
21933	34	1202.0	5371.0	1041.0	5055.0	1197.2	5371.8	1036.7	5060.1	648564,48	42952,00	649594,25	42920,72
21934	35	1202.0	5368.0	.0	.0	1195.0	5368.8	1035.2	5056.6	648575,85	42950,31	649604,67	42921,57
21935	36	1202.0	5363.0	.0	.0	1194.3	5365.4	1033.0	5053.1	648587,14	42948,43	649615,55	42922,48
21936	37	1194.0	5364.0	1036.0	5044.0	1192.6	5361.4	1031.5	5049.4	648598,42	42946,65	649627,28	42924,75
21937	38	1194.0	5356.0	.0	.0	1190.6	5358.2	1029.9	5045.7	648609,83	42945,06	649639,41	42922,75
21938	39	1193.0	5356.0	.0	5031.0	1189.1	5354.8	1028.4	5042.3	648621,70	42943,59	649651,72	42922,54
21939	40	1193.0	5353.0	.0	.0	1186.9	5351.1	1027.1	5038.5	648633,65	42942,87	649664,27	42921,76
21940	41	1192.0	5348.0	.0	.0	1184.6	5347.7	1025.9	5034.3	648645,72	42941,92	649677,01	42920,63
21941	42	1185.0	5342.0	1026.0	5022.0	1182.4	5343.7	1024.6	5030.4	648657,81	42941,34	649690,95	42919,38
21942	43	1183.0	5339.0	.0	.0	1179.6	5340.0	1023.5	5026.5	648670,20	42940,88	649704,42	42917,88
21943	44	1185.0	5338.0	1025.0	5015.0	1178.2	5336.1	1022.0	5021.3	648682,55	42940,25	649717,81	42916,48
21944	45	1180.0	5332.0	.0	.0	1175.7	5332.6	1020.8	5017.5	648694,93	42939,09	649730,82	42915,33
21945	46	1177.0	5324.0	.0	.0	1173.7	5328.5	1019.7	5011.8	648706,99	42937,57	649742,66	42914,65
21946	47	1176.0	5326.0	.0	5002.0	1171.7	5324.9	1018.6	5010.2	648718,95	42935,63	649754,71	42914,15
21947	48	1175.0	5319.0	.0	.0	1170.4	5321.6	1017.1	5006.8	648730,62	42934,38	649765,80	42913,90
21948	49	1171.0	5320.0	.0	.0	1169.2	5318.3	1015.6	5004.9	648742,19	42932,78	649777,14	42913,26
21949	50	1178.0	5315.0	1021.0	4996.0	1167.4	5314.9	1014.6	5001.3	648753,37	42931,56	649788,33	42912,86
21950	51	1168.0	5311.0	.0	.0	1165.2	5311.4	1013.3	4997.7	648764,44	42930,62	649799,20	42912,20
21951	52	1171.0	5307.0	1016.0	4988.0	1163.5	5308.2	1012.8	4993.5	648775,55	42930,44	649810,30	42911,62
21952	53	1166.0	5306.0	.0	.0	1161.4	5304.9	1011.4	4990.1	648786,84	42930,84	649822,14	42910,88
21953	54	1164.0	5302.0	.0	.0	1159.2	5301.4	1010.9	4987.0	648798,02	42932,15	649833,88	42910,57
21954	55	1161.0	5298.0	1010.0	4973.0	1156.5	5298.0	1009.4	4983.4	648809,06	42933,41	649845,59	42910,38
21955	56	1157.0	5295.0	.0	.0	1154.2	5294.2	1007.9	4979.8	648820,19	42935,16	649857,02	42910,76
21956	57	1156.0	5290.0	.0	.0	1151.0	5290.9	1005.9	4976.4	648831,50	42936,76	649868,95	42911,65
21957	58	1155.0	5287.0	1007.0	4968.0	1149.1	5287.7	1004.5	4972.8	648842,93	42938,07	649881,12	42912,85
21958	59	1152.0	5284.0	.0	.0	1146.5	5284.3	1003.2	4969.2	648854,46	42938,81	649893,02	42913,49
21959	60	1150.0	5280.0	1003.0	4956.0	1144.4	5280.5	1000.5	4964.6	648866,23	42939,07	649905,01	42914,12
220 0	61	1146.0	5276.0	.0	.0	1142.6	5276.9	999.2	4960.9	648878,48	42938,19	649917,20	42914,49
220 1	62	1147.0	5275.0	.0	.0	1140.8	5273.3	999.2	4956.0	648891,25	42936,86	649929,41	42915,18
220 2	63	1141.0	5271.0	1002.0	4947.0	1139.1	5269.1	997.7	4954.2	648904,29	42935,07	649941,65	42915,79
220 3	64	1144.0	5266.0	.0	.0	1137.3	5265.0	996.1	4950.6	648917,37	42933,13	649953,52	42915,78
220 4	65	1140.0	5260.0	.0	.0	1135.7	5260.7	994.2	4946.7	648930,66	42931,19	649965,92	42915,86
220 5	66	1139.0	5256.0	999.0	4937.0	1133.6	5256.8	993.0	4943.0	648944,22	42929,69	649978,70	42916,22
220 6	67	1139.0	5252.0	.0	.0	1131.8	5253.0	991.9	4939.3	648957,54	42928,58	649991,02	42916,19
220 7	68	1134.0	5248.0	988.0	4924.0	1129.8	5248.9	990.2	4934.5	648970,65	42927,98	650003,30	42915,86
220 8	69	1133.0	5242.0	.0	.0	1127.0	5244.7	989.4	4930.8	648983,30	42927,77	650015,67	42914,96
220 9	70	1131.0	5243.0	.0	.0	1125.0	5240.9	989.1	4928.0	648995,71	42927,61	650028,44	42913,82
22010	71	1127.0	5239.0	995.0	4918.0	1122.6	5237.2	988.3	4924.3	649008,07	42927,30	650041,16	42912,59
22011	72	1123.0	5236.0	.0	.0	1120.9	5233.9	987.5	4920.5	649020,23	42926,69	650053,30	42911,11
22012	73	1126.0	5230.0	.0	.0	1119.0	5230.4	986.7	4916.0	649032,12	42925,47	650065,41	42909,26
22013	74	1125.0	5224.0	990.0	4907.0	1117.7	5226.7	985.9	4912.4	649044,16	42923,82	650077,81	42907,53
22014	75	1119.0	5222.0	.0	.0	1116.5	5223.1	985.2	4908.9	649056,19	42921,63	650089,53	42905,39
22015	76	1124.0	5220.0	988.0	4896.0	1115.2	5219.5	985.2	4905.3	649068,31	42919,57	650101,14	42903,21
22016	77	1120.0	5216.0	.0	.0	1113.8	5215.5	984.6	4901.9	649080,19	42917,96	650112,30	42901,14
22017	78	1118.0	5214.0	.0	.0	1112.5	5211.9	985.1	4899.7	649091,80	42917,18	650123,77	42899,72
22018	79	1116.0	5208.0	987.0	4890.0	1110.5	5208.8	984.6	4896.2	649103,41	42917,39	650135,26	42898,40
22019	80	1115.0	5204.0	.0	.0	1108.2	5205.3	983.9	4892.6	649115,17	42918,26	650146,72	42897,38
22020	81	1110 0	5202.0	.0	.0	1105.7	5202.1	981.7	4888.3	649126,91	42919,47	650157,97	42896,87
22021	82	1108.0	5198.0	986.0	4880.0	1102.9	5198.4	980.9	4884.7	649138,72	42921,07	650169,91	42896,67
22022	83	1105.0	5194.0	.0	.0	1100.2	5194.8	980.1	4881.1	649150,50	42922,86	650181,79	42896,46
22023	84	1103.0	5191.0	984.0	4868.0	1098.3	5190.3	979.3	4878.1	649162,88	42922,99	650193,83	42896,22
22024	85	1099.0	5188.0	.0	.0	1096.3	5186.5	978.5	4874.3	649175,63	42922,73	650205,80	42895,30
22025	86	1100.0	5185.0	.0	.0	1094.8	5183.1	978.1	4871.0	649188,51	42921,77	650218,68	42894,09
22026	87	1096.0	5178.0	.0	4860.0	1093.4	5179.0	977.5	4867.1	649201,23	42920,27	650231,71	42892,62
22027	88	1100.0	5173.0	.0	.0	1091.9	5174.9	976.9	4863.0	649213,84	42918,84	650245,23	42891,46
22028	89	1098.0	5169.0	980.0	4849.0	1090.3	5171.2	976.2	4857.5	649226,47	42917,54	650258,82	42890,13
22029	90	1094.0	5164.0	.0	.0	1088.9	5167.5	975.5	4851.6	649239,26	42916,58	650272,42	42889,01
22030	91	1092.0	5166.0	.0	.0	1087.5	5163.7	974.8	4849.6	649251,71	42916,12	650285,91	42888,21
22031	92	1092.0	5160.0	978.0	4836.0	1084.9	5159.9	974.0	4845.7	649263,98	42916,09	650299,12	42887,58
22032	93	1087.0	5154.0	.0	.0	1082.6	5156.6	973.2	4841.8	649276,55	42916,33	650311,59	42887,28
22033	94	1083.0	5154.0	.0	.0	1080.8	5152.6	972.3	4838.9	649288,96	42916,73	650324,32	42887,06
22034	95	1085.0	5150.0	977.0	4830.0	1078.7	5148.8	971.6	4835.0	649301,77	42917,30	650337,03	42886,90
22035	96	1082.0	5145.0	.0	.0	1076.7	5144.9	970.6	4831.0	649314,67	42917,94	650349,81	42886,78
22036	97	1078.0	5139.0	973.0	4819.0	1074.7	5140.0	969.7	4826.6	649327,59	42917,14	650362,53	42886,71
22037	98	1078.0	5136.0	.0	.0	1072.5	5136.3	969.0	4822.6	649341,10	42916,21	650375,63	42886,53
22038	99	1080.0	5132.0	.0	.0	1070.9	5132.6	968.2	4818.5	649354,91	42915,08	650388,52	42886,69
22039	100	1077.0	5130.0	971.0	4805.0	1069.8	5128.6	967.4	4814.8	649368,73	42913,70	650401,32	42886,74
22040	101	1072.0	5124.0	.0	.0	1068.5	5124.0	966.6	4811.1	649382,15	42912,50	650413,79	42886,81
22041	102	1067.0	5120.0	.0	.0	1066.6	5119.6	965.6	4807.6	649395,93	42910,83	650426,30	42886,93
22042	103	1070.0	5115.0	970.0	4795.0	1065.1	5115.7	964.7	4803.8	649409,64	42909,36	650438,80	42886,96
22043	104	1069.0	5111.0	.0	.0	1063.4	5111.9	964.8	4800.8	649423,58	42908,19	650451,50	42886,83
22044	105	1072.0	5109.0	.0	.0	1061.6	5107.7	963.4	4796.0	649437,14	42907,41	650464,07	42886,35
22045	106	1066.0	5104.0	967.0	4788.0	1059.8	5103.6	962.9	4791.9	649450,46	42906,71	650476,97	42885,67
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

Table A.8 Page Two, Center of Gravity and Yaw Data

HHMMSS	TIME SECS	LCG/LCG X,Y DATA,FT XXXXXX.XX	YYYYYY.YY	HEADING DEGREES	LCG VELOCITY,FEET/SEC. D(X)/DT	D(Y)/DT	D(U)/DT	YAW RATE DEG./SEC	DRFT ANG DEGREES	LCG ACCELERATION,FT/SEC2 D2X/DT2	D2Y/DT2	D2U/DT2	YAW ACC. DEG/SEC2	RUDDR DEGR.
219 0	1	648712.60	42955.99	358.448	.000	.000	.000	.10327	.000	.00000	.00000	.00000	.00002	3.4
219 1	2	648723.20	42954.86	358.551	.000	.000	.000	.10324	.000	.00000	.00000	.00000	.00002	3.4
219 2	3	648733.80	42953.73	358.655	.000	.000	.000	.10336	.000	.00000	.00000	.00000	.00011	3.4
219 3	4	648744.40	42952.60	358.758	.000	.000	.000	.09920	.000	.00000	.00000	.00000	-.00843	3.4
219 4	5	648755.05	42951.54	358.853	.000	.000	.000	.09071	.000	.00000	.00000	.00000	-.00855	3.4
219 5	6	648765.87	42950.57	358.939	.000	.000	.000	.07810	.000	.00000	.00000	.00000	-.01455	3.4
219 6	7	648776.81	42949.76	359.009	.000	.000	.000	.05691	.000	.00000	.00000	.00000	-.02185	3.4
219 7	8	648787.70	42949.15	359.057	.000	.000	.000	.03446	.000	.00000	.00000	.00000	-.01900	3.4
219 8	9	648798.59	42948.72	359.084	.000	.000	.000	.00929	.000	.00000	.00000	.00000	-.03431	3.4
219 9	10	648809.39	42944.65	359.076	.000	.000	.000	-.01859	.000	.00000	.00000	.00000	-.01444	3.4
21910	11	648820.37	42944.72	359.049	.000	.000	.000	-.02667	.000	.00000	.00000	.00000	.00028	3.4
21911	12	648831.47	42944.76	359.022	.000	.000	.000	-.03556	.000	.00000	.00000	.00000	-.01807	3.4
21912	13	648842.60	42944.90	358.978	.000	.000	.000	-.03715	.000	.00000	.00000	.00000	.01440	3.4
21913	14	648853.87	42944.41	358.944	.000	.000	.000	-.02440	.000	.00000	.00000	.00000	.00059	3.4
21914	15	648865.34	42944.78	358.919	.000	.000	.000	-.02053	.000	.00000	.00000	.00000	.01715	3.4
21915	16	648877.09	42944.44	358.907	.000	.000	.000	.00310	.000	.00000	.00000	.00000	.03011	3.4
21916	17	648888.91	42944.60	358.925	.000	.000	.000	.01414	.000	.00000	.00000	.00000	-.00602	3.4
21917	18	648900.54	42944.22	358.935	.000	.000	.000	.00456	.000	.00000	.00000	.00000	-.01219	3.4
21918	19	648912.10	42943.56	358.933	.000	.000	.000	-.00856	.000	.00000	.00000	.00000	-.01306	3.4
21919	20	648923.66	42942.57	358.914	.000	.000	.000	-.03062	.000	.00000	.00000	.00000	-.03101	.0
21920	21	648935.00	42944.18	358.872	.000	.000	.000	-.05928	.000	.00000	.00000	.00000	-.02432	.0
21921	22	648946.18	42944.55	358.800	.000	.000	.000	-.08341	.000	.00000	.00000	.00000	-.02274	.0
21922	23	648957.11	42943.15	358.704	.000	.000	.000	-.11299	.000	.00000	.00000	.00000	-.01557	.0
21923	24	648968.06	42941.77	358.590	.000	.000	.000	-.12494	.000	.00000	.00000	.00000	-.03245	.0
21924	25	648979.06	42940.85	358.451	.000	.000	.000	-.14467	.000	.00000	.00000	.00000	-.01302	.0
21925	26	648989.99	42939.34	358.294	.000	.000	.000	-.13661	.000	.00000	.00000	.00000	.03915	.0
21926	27	649001.02	42938.61	358.177	.000	.000	.000	-.11509	.000	.00000	.00000	.00000	.03389	.0
21927	28	649012.01	42937.87	358.068	.000	.000	.000	-.09543	.000	.00000	.00000	.00000	.03562	.0
21928	29	649023.25	42937.32	357.987	.000	.000	.000	-.05315	.000	.00000	.00000	.00000	.04914	.0
21929	30	649034.89	42936.96	357.956	.000	.000	.000	-.02100	.000	.00000	.00000	.00000	.01517	.0
21930	31	649046.08	42936.66	357.945	.000	.000	.000	.01947	.000	.00000	.00000	.00000	.04417	.0
21931	32	649057.22	42936.30	357.997	.000	.000	.000	.08436	.000	.00000	.00000	.00000	.06122	.0
21932	33	649068.54	42935.89	358.113	.000	.000	.000	.11766	.000	.00000	.00000	.00000	.00337	.0
21933	34	649079.43	42935.59	358.233	.000	.000	.000	.12951	.000	.00000	.00000	.00000	.02034	.0
21934	35	649091.24	42935.17	358.372	.000	.000	.000	.14726	.000	.00000	.00000	.00000	.01517	.0
21935	36	649102.57	42934.68	358.527	.000	.000	.000	.13467	.000	.00000	.00000	.00000	-.04034	.0
21936	37	649113.88	42933.93	358.642	.000	.000	.000	.10207	.000	.00000	.00000	.00000	-.02487	.0
21937	38	649125.30	42933.14	358.731	.000	.000	.000	.08012	.000	.00000	.00000	.00000	-.01902	.0
21938	39	649137.19	42932.31	358.802	.000	.000	.000	.03385	.000	.00000	.00000	.00000	-.07351	.0
21939	40	649149.14	42931.56	358.799	.000	.000	.000	-.00582	.000	.00000	.00000	.00000	-.00585	.0
21940	41	649161.21	42930.53	358.790	.000	.000	.000	-.02364	.000	.00000	.00000	.00000	-.02978	.0
21941	42	649173.30	42929.66	358.752	.000	.000	.000	-.04490	.000	.00000	.00000	.00000	-.01274	.0
21942	43	649185.66	42928.65	358.700	.000	.000	.000	-.04734	.000	.00000	.00000	.00000	.00766	.0
21943	44	649198.02	42927.67	358.657	.000	.000	.000	-.02101	.000	.00000	.00000	.00000	.04460	.0
21944	45	649210.39	42926.52	358.658	.000	.000	.000	.02603	.000	.00000	.00000	.00000	.04527	.0
21945	46	649222.67	42925.42	358.705	.000	.000	.000	.06276	.000	.00000	.00000	.00000	.03217	.0
21946	47	649234.44	42924.19	358.784	.000	.000	.000	.06678	.000	.00000	.00000	.00000	-.02413	.0
21947	48	649246.12	42923.43	358.839	.000	.000	.000	.05394	.000	.00000	.00000	.00000	-.00155	.0
21948	49	649257.70	42922.31	358.892	.000	.000	.000	.04923	.000	.00000	.00000	.00000	-.00787	2.5
21949	50	649268.88	42921.50	358.937	.000	.000	.000	.03032	.000	.00000	.00000	.00000	-.02995	2.5
21950	51	649279.96	42920.69	358.952	.000	.000	.000	-.00322	.000	.00000	.00000	.00000	-.03715	2.5
21951	52	649291.06	42920.32	358.931	.000	.000	.000	-.04226	.000	.00000	.00000	.00000	-.04093	2.5
21952	53	649302.35	42920.13	358.868	.000	.000	.000	-.07583	.000	.00000	.00000	.00000	-.02622	2.5
21953	54	649313.50	42920.66	358.779	.000	.000	.000	-.08622	.000	.00000	.00000	.00000	.00945	2.5
21954	55	649324.55	42921.21	358.699	.000	.000	.000	-.07724	.000	.00000	.00000	.00000	.04452	2.5
21955	56	649335.64	42922.28	358.624	.000	.000	.000	-.05713	.000	.00000	.00000	.00000	.03569	2.5
21956	57	649346.95	42923.54	358.585	.000	.000	.000	-.02201	.000	.00000	.00000	.00000	.03455	2.5
21957	58	649358.37	42924.80	358.580	.000	.000	.000	-.00477	.000	.00000	.00000	.00000	-.00008	2.5
21958	59	649369.91	42925.50	358.576	.000	.000	.000	.00780	.000	.00000	.00000	.00000	.02523	2.5
21959	60	649381.68	42925.94	358.596	.000	.000	.000	.04476	.000	.00000	.00000	.00000	.04869	2.5
220 0	61	649393.95	42925.68	358.665	.000	.000	.000	.09012	.000	.00000	.00000	.00000	.04203	2.5
220 1	62	649406.73	42925.35	358.776	.000	.000	.000	.12111	.000	.00000	.00000	.00000	.01995	2.5
220 2	63	649419.80	42924.74	358.907	.000	.000	.000	.11841	.000	.00000	.00000	.00000	-.02536	4.1
220 3	64	649432.90	42923.75	359.013	.000	.000	.000	.10831	.000	.00000	.00000	.00000	.00517	5.3
220 4	65	649446.20	42922.90	359.124	.000	.000	.000	.10666	.000	.00000	.00000	.00000	-.00847	5.3
220 5	66	649459.78	42922.23	359.226	.000	.000	.000	.08091	.000	.00000	.00000	.00000	-.04303	5.3
220 6	67	649473.11	42921.65	359.286	.000	.000	.000	.03680	.000	.00000	.00000	.00000	-.04517	5.3
220 7	68	649486.22	42921.18	359.300	.000	.000	.000	-.01218	.000	.00000	.00000	.00000	-.05279	5.3
220 8	69	649498.87	42920.62	359.261	.000	.000	.000	-.04632	.000	.00000	.00000	.00000	-.01509	5.3
220 9	70	649511.27	42919.98	359.207	.000	.000	.000	-.05266	.000	.00000	.00000	.00000	.00321	5.3
22010	71	649523.62	42919.21	359.157	.000	.000	.000	-.04972	.000	.00000	.00000	.00000	.00227	5.3
22011	72	649535.77	42918.16	359.108	.000	.000	.000	-.04102	.000	.00000	.00000	.00000	.01434	5.3
22012	73	649547.66	42916.63	359.074	.000	.000	.000	-.01928	.000	.00000	.00000	.00000	.02994	5.3
22013	74	649559.70	42914.95	359.069	.000	.000	.000	-.00092	.000	.00000	.00000	.00000	.00677	5.3
22014	75	649571.73	42912.78	359.072	.000	.000	.000	-.00211	.000	.00000	.00000	.00000	-.00914	5.3
22015	76	649583.85	42910.66	359.065	.000	.000	.000	-.01686	.000	.00000	.00000	.00000	-.01956	5.3
22016	77	649595.72	42908.81	359.039	.000	.000	.000	-.03102	.000	.00000	.00000	.00000	-.00957	5.3
22017	78	649607.36	42907.71	359.003	.000	.000	.000	-.06064	.000	.00000	.00000	.00000	-.04967	6.9
22018	79	649618.92	42907.15	358.918	.000	.000	.000	-.09084	.000	.00000	.00000	.00000	-.01072	.8
22019	80	649630.67	42907.16	358.821	.000	.000	.000	-.10068	.000	.00000	.00000	.00000	-.00896	.8
22020	81	649642.39	42907.82	358.710	.000	.000	.000	-.10229	.000	.00000	.00000	.00000	.00573	.8
22021	82	649654.17	42908.13	358.617	.000	.000	.000	-.09615	.000	.00000	.00000	.00000	.01054	.8
22022	83	649665.93	42909.71	358.528	.000	.000	.000	-.06587	.000	.00000	.00000	.00000	.04603	.8
22023	84	649678.26	42908.86	358.485	.000	.000	.000	-.04042	.000	.00000	.00000	.00000	.00486	.8
22024	85	649691.05	42908.26	358.467	.000	.000	.000	-.02582	.000	.00000	.00000	.00000	.02436	.8
22025	86	649703.91	42907.17	358.434	.000	.000	.000	-.00022	.000	.00000	.00000	.00000	.02683	.8
22026	87	649716.66	42905.79	358.447	.000	.000	.000	.00920	.000	.00000	.00000	.00000	-.00797	.8
22027	88	649729.76	42904.61	358.452	.000	.000	.000	.00282	.000	.00000	.00000	.00000	-.00559	.8
22028	89	649741.88	42903.11	358.452	.000	.000	.000	-.00390	.000	.00000	.00000	.00000	-.00706	.8
22029	90	649754.69	42902.08	358.444	.000	.000	.000	-.01254	.000	.00000	.00000	.00000	-.01021	.8
22030	91	649767.12	42901.66	358.426	.000	.000	.000	-.02471	.000	.00000	.00000	.00000	-.01418	.8
22031	92	649779.38	42901.14	358.395	.000	.000	.000	-.03067	.000	.00000	.00000	.00000	.00220	.8
22032	93	649791.72	42901.12	358.369	.000	.000	.000	-.03181	.000	.00000	.00000	.00000	-.00848	.8
22033	94	649804.34	42901.21	358.331	.000	.000	.000	-.03745	.000	.00000	.00000	.00000	-.00680	.8
22034	95	649817.15	42901.42	358.290	.000	.000	.000	-.03068	.000	.00000	.00000	.00000	.02087	.8
22035	96	649830.08	42901.87	358.270	.000	.000	.000	-.00097	.000	.00000	.00000	.00000	.03803	.8
22036	97	649842.99	42901.26	358.288	.000	.000	.000	.02954	.000	.00000	.00000	.00000	.02300	.8
22037	98	649856.48	42900.60	358.329	.000	.000	.000	.05421	.000	.00000	.00000	.00000	.02632	.8
22038	99	649870.51	42900.15	358.397	.000	.000	.000	.07372	.000	.00000	.00000	.00000	.01270	.8
22039	100	649884.16	42899.69	358.477	.000	.000	.000	.08006	.000	.00000	.00000	.00000	-.00001	.8
22040	101	649897.79	42898.81	358.557	.000	.000	.000	.08335	.000	.00000	.00000	.00000	.00058	.8
22041	102	649911.39	42898.12	358.643	.000	.000	.000	.08635	.000	.00000	.00000	.00000	-.05459	.8
22042	103	649925.12	42897.39	358.726	.000	.000	.000	.06921	.000	.00000	.00000	.00000	-.02568	.8
22043	104	649939.07	42896.73	358.782	.000	.000	.000	.01403	.000	.00000	.00000	.00000	-.04076	.8
22044	105	649952.63	42896.09	358.798	.000	.000	.000	.00250	.000	.00000	.00000	.00000	-.02021	.8
22045	106	649965.95	42895.29	358.787	.000	.000	.000	-.01961	.000	.00000	.00000	.00000	-.01769	.8
		(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)

Table A.9 Page Two, Smoothed Velocity and Acceleration Data

TIME HHMMSS	SECS	LCB/LCG X,Y DATA,FT XXXXXX.XX	YYYYYY.YY	HEADING DEGREES	LCB VELOCITY,FEET/SEC. D(X)/DT	D(Y)/DT	D(U)/DT	YAW RATE DEG./SEC	DRFT ANG DEGREES	LCB ACCELERATION,FT/SEC2 D2X/DT2	D2Y/DT2	D2U/DT2	YAW ACC. DEG/SEC2	RUDDR DEGR.
219 0	1	648712.59	42955.97	358.448	10.609	-1.115	10.668	.10327	4.448	.00505	.00000	.00000	.00002	3.4
219 1	2	648723.20	42954.86	358.551	10.609	-1.115	10.668	.10329	4.551	.00000	.00000	.00000	.00008	3.4
219 2	3	648733.80	42953.74	358.655	10.609	-1.115	10.668	.10336	4.655	.02578	.02017	.03273	.00011	3.4
219 3	4	648744.46	42952.66	358.758	10.661	-1.075	10.715	.09920	4.515	.07070	.05981	.09261	-.00843	3.4
219 4	5	648755.18	42951.64	358.853	10.751	-.996	10.797	.09071	4.143	.08750	.10361	.13562	-.00855	3.4
219 5	6	648765.96	42950.72	358.939	10.836	-.868	10.871	.07816	3.517	.07031	.14390	.16016	-.01455	3.4
219 6	7	648776.80	42949.95	359.009	10.891	-.708	10.914	.05891	2.727	.02266	.18699	.19038	-.02195	3.4
219 7	8	648787.67	42949.37	359.057	10.881	-.490	10.892	.03844	1.633	-.00469	.22582	.22527	-.01900	3.4
219 8	9	648798.57	42949.00	359.086	10.892	-.257	10.885	.00929	.441	.02576	.20632	.20793	-.03931	3.4
219 9	10	648809.50	42948.80	359.076	10.933	-.077	10.933	-.01899	-.521	.06567	.15696	.16938	-.01644	3.4
21910	11	648820.48	42948.76	359.049	11.009	.057	11.010	-.02667	-1.266	.09258	.12534	.15562	.00028	3.4
21911	12	648831.54	42948.80	359.022	11.118	.174	11.119	-.03556	-1.873	.11211	.10994	.15702	-.01807	3.4
21912	13	648842.73	42949.12	358.978	11.236	.277	11.237	-.03715	-2.432	.13984	.06670	.15696	.01490	3.4
21913	14	648854.07	42949.35	358.948	11.398	.307	11.402	-.02980	-2.599	.17461	-.04260	.17973	.00059	3.4
21914	15	648865.55	42949.53	358.919	11.563	.191	11.588	-.02053	-2.027	.14668	-.17781	.23018	.01715	3.4
21915	16	648877.14	42949.59	358.907	11.691	-.048	11.691	.00310	-.855	.05703	-.25027	.25608	.03011	3.4
21916	17	648888.79	42949.42	358.925	11.697	-.309	11.701	.01418	.440	-.02852	-.26113	.26269	-.00602	3.4
21917	18	648900.45	42948.98	358.935	11.634	-.571	11.648	.00404	1.744	-.08320	-.27064	.28069	-.01219	3.4
21918	19	648912.04	42948.24	358.933	11.530	-.862	11.563	-.00898	3.209	-.10761	-.29656	.31743	-.01306	3.4
21919	20	648923.49	42947.22	358.918	11.418	-1.168	11.478	-.03062	4.758	-.13828	-.25986	.29436	-.03101	.0
21920	21	648934.80	42946.01	358.872	11.254	-1.382	11.338	-.05926	5.473	-.14523	-.14716	.22125	-.02632	.0
21921	22	648945.99	42944.65	358.800	11.087	-1.462	11.183	-.08361	6.312	-.12773	-.01914	.12916	-.02274	.0
21922	23	648957.07	42943.23	358.704	10.998	-1.420	11.090	-.10295	6.062	-.06484	.09385	.11407	-.01552	.0
21923	24	648968.07	42941.81	358.590	10.958	-1.274	11.032	-.12694	5.728	-.01094	.14451	.14492	-.03245	.0
21924	25	648979.04	42940.71	358.451	10.977	-1.131	11.035	-.14967	4.334	.01563	.15361	.15441	-.01302	.0
21925	26	648990.02	42939.66	358.294	10.989	-.967	11.032	-.13661	3.325	.03129	.16616	.16906	.03915	.0
21926	27	649001.06	42938.77	358.177	11.039	-.799	11.068	-.11509	2.316	.08672	.16233	.18404	.00389	.0
21927	28	649012.19	42938.00	358.064	11.162	-.623	11.181	-.09543	1.359	.11660	.15957	.19775	.03542	.0
21928	29	649023.40	42937.49	357.987	11.273	-.400	11.283	-.05315	.423	.07930	.13169	.15355	.04018	.0
21929	30	649034.63	42937.03	357.959	11.321	-.380	11.327	-.02100	-.122	.01914	.06284	.06569	.01517	.0
21930	31	649045.95	42936.63	357.945	11.311	-.394	11.316	.01967	-.263	-.02148	.01282	.02502	.06617	.0
21931	32	649057.28	42936.28	357.997	11.278	-.359	11.284	.08436	-.209	-.00409	-.00815	.00981	.06322	.0
21932	33	649068.57	42935.92	358.113	11.302	-.370	11.308	.11766	-.010	.03125	-.02148	.03792	.00337	.0
21933	34	649079.87	42935.53	358.255	11.341	-.397	11.348	.12951	.237	.02070	-.05645	.06012	.02038	.0
21934	35	649091.21	42935.05	358.372	11.343	-.463	11.353	.14726	.811	.00938	-.10889	.10929	.01517	.0
21935	36	649102.56	42934.50	358.527	11.359	-.615	11.376	.13667	1.025	.05977	-.12144	.13535	-.04034	.0
21936	37	649114.03	42933.84	358.642	11.402	-.726	11.445	.10207	2.266	.14256	-.05566	.16632	-.02887	.0
21937	38	649125.62	42933.12	358.731	11.645	-.786	11.671	.08012	2.593	.19336	-.05566	.20121	-.01902	.0
21938	39	649137.34	42932.29	358.802	11.849	-.837	11.879	.03585	2.846	.17812	-.00391	.18336	-.07351	.0
21939	40	649149.23	42931.44	358.799	12.001	-.873	12.032	-.00582	2.960	.13066	-.04221	.13750	-.00585	.0
21940	41	649161.30	42930.54	358.790	12.111	-.922	12.146	-.02364	3.143	.10977	-.04688	.11936	-.02978	.0
21941	42	649173.46	42929.61	358.752	12.220	-.967	12.258	-.04490	3.275	.09844	-.04036	.10639	-.01274	.0
21942	43	649185.71	42928.60	358.700	12.338	-1.002	12.369	-.04734	3.357	.04336	-.04741	.06825	.02786	.0
21943	44	649197.96	42927.58	358.657	12.337	-1.062	12.353	-.02101	3.587	-.05391	-.05706	.07651	.04480	.0
21944	45	649210.19	42926.49	358.658	12.200	-1.117	12.251	.02403	3.888	-.14102	-.00933	.14132	.04527	.0
21945	46	649222.28	42925.44	358.705	12.025	-1.080	12.073	.04276	3.638	-.16711	.03631	.19099	.03217	.0
21946	47	649234.22	42924.37	358.784	11.826	-1.040	11.871	.06678	3.810	-.20820	.05398	.21509	-.02813	.0
21947	48	649245.91	42923.37	358.839	11.609	-.972	11.649	.05594	3.626	-.22227	.07375	.23418	-.00155	.0
21948	49	649257.41	42922.42	358.892	11.381	-.893	11.416	.04923	3.376	-.19608	.09407	.21784	-.00787	2.5
21949	50	649268.74	42921.65	358.937	11.216	-.764	11.243	.03032	2.936	-.11602	.17180	.20731	-.02995	2.5
21950	51	649279.98	42920.09	358.952	11.149	-.549	11.163	-.00322	1.771	-.02656	.28184	.28308	-.03715	2.5
21951	52	649291.15	42920.67	358.931	11.162	-.220	11.165	-.04226	.062	.00430	.34353	.34356	-.04003	2.5
21952	53	649302.27	42920.61	358.868	11.158	.138	11.159	-.07583	-1.841	-.01445	.35906	.35437	-.02622	2.5
21953	54	649313.41	42921.42	358.779	11.134	.498	11.145	-.08422	-3.781	-.01250	.35063	.35066	.00945	2.5
21954	55	649324.54	42921.97	358.699	11.133	.839	11.164	-.07724	-5.612	.04141	.28142	.28045	.00452	2.5
21955	56	649335.80	42922.50	358.624	11.216	1.061	11.266	-.05713	-6.777	.10781	.13484	.17264	.03569	2.5
21956	57	649347.28	42923.47	358.585	11.348	1.109	11.403	-.02201	-6.907	.16375	-.08446	.15837	.03455	2.5
21957	58	649358.51	42924.41	358.580	11.524	.928	11.561	.00477	-6.030	.19102	-.28372	.34263	-.00008	2.5
21958	59	649370.17	42925.09	358.576	11.730	.542	11.743	.00790	-4.088	.28594	-.37493	.49155	.02523	2.5
21959	60	649382.12	42925.45	358.598	12.076	.120	12.076	.00876	-2.011	.37734	-.37615	.53280	.00869	2.5
220 0	61	649394.41	42925.44	358.665	12.435	-.211	12.487	.00912	-.368	.37695	-.33040	.50125	.00203	2.5
220 1	62	649407.01	42925.09	358.776	12.830	-.533	12.841	.12111	1.154	.29141	-.24240	.39814	.01995	2.5
220 2	63	649419.80	42924.46	358.907	13.068	-.735	13.089	.11841	2.129	.20977	-.14199	.25330	-.02536	4.1
220 3	64	649433.08	42923.77	359.013	13.249	-.817	13.274	.10831	2.541	.14063	-.01726	.14168	.00517	5.3
220 4	65	649446.35	42923.03	359.124	13.349	-.770	13.371	.10666	2.425	.05273	.09351	.10735	-.00847	5.3
220 5	66	649459.62	42922.32	359.226	13.355	-.630	13.370	.08091	1.926	-.08633	.11384	.14287	-.04303	5.3
220 6	67	649472.83	42921.70	359.284	13.177	-.502	13.188	.03680	1.443	-.24023	.03811	.24324	-.04517	5.3
220 7	68	649485.84	42921.13	359.300	12.874	-.554	12.946	-.01218	1.762	-.26398	-.03240	.28583	-.05279	5.3
220 8	69	649498.42	42920.53	359.261	12.609	-.607	12.623	-.04632	2.018	-.24375	-.09480	.26154	-.01549	5.3
220 9	70	649511.16	42919.43	359.207	12.387	-.763	12.409	-.05206	2.601	-.19961	-.15555	.27253	.00321	5.3
22010	71	649523.45	42918.02	359.157	12.209	-.978	12.248	-.04972	3.737	-.14922	-.26033	.30006	.00227	5.3
22011	72	649535.61	42917.79	359.108	12.088	-1.264	12.154	-.00162	5.077	-.09844	-.31555	.33055	.01434	5.3
22012	73	649547.70	42916.35	359.074	12.013	-1.609	12.120	-.01928	6.704	-.03320	-.31191	.31368	.02994	5.3
22013	74	649559.73	42914.64	359.069	12.022	-1.888	12.169	-.00092	7.993	.00703	-.19263	.19276	.00677	5.3
22014	75	649571.73	42912.76	359.072	12.027	-1.995	12.191	-.00211	8.488	-.04727	.02153	.05194	-.00914	5.3
22015	76	649583.66	42910.98	359.065	11.927	-1.845	12.069	-.01666	7.856	-.11953	.28777	.31161	-.01956	5.3
22016	77	649595.51	42909.42	359.039	11.767	-1.459	11.873	-.03102	5.903	-.12148	.48999	.50483	-.00957	5.3
22017	78	649607.30	42908.30	359.003	11.684	-.865	11.716	-.06064	3.235	-.05977	.54348	.54676	-.04967	4.9
22018	79	649619.01	42907.65	358.919	11.668	-.332	11.673	-.09084	.568	.01484	.48745	.48768	-.01072	.8
22019	80	649630.70	42907.51	358.821	11.714	.110	11.715	-.10068	-1.718	.04180	.37026	.37262	-.00896	.8
22020	81	649642.41	42907.71	358.716	11.752	.408	11.759	-.10229	-3.275	.07852	.17957	.19598	.00573	.8
22021	82	649654.28	42906.06	358.617	11.871	.669	11.890	-.09415	-3.648	.19414	-.06396	.21153	.01054	.8
22022	83	649666.35	42906.28	358.528	12.140	.241	12.142	-.06587	-2.607	.29483	-.35286	.45963	.04603	.8
22023	84	649678.66	42906.23	358.455	12.400	-.236	12.402	-.04042	-.426	.28398	-.49663	.57209	.00486	.8
22024	85	649691.16	42907.76	358.447	12.708	-.753	12.730	-.02582	1.837	.14961	-.45015	.47436	.02836	.8
22025	86	649703.82	42906.90	358.434	12.759	-1.137	12.810	-.00022	3.524	-.00313	-.27676	.27678	.02683	.8
22026	87	649716.55	42905.75	358.447	12.702	-1.300	12.769	.00920	4.318	-.04180	-.07510	.08595	-.00797	.8
22027	88	649729.27	42904.51	358.452	12.676	-1.287	12.741	.00242	4.248	-.03242	.10361	.10837	-.00599	.8
22028	89	649741.91	42903.37	358.452	12.637	-1.099	12.686	-.00390	3.622	-.06367	.23485	.24294	-.00706	.8
22029	90	649754.46	42902.46	358.448	12.548	-.818	12.575	-.01254	2.173	-.09922	.30376	.31955	-.01021	.8
22030	91	649766.95	42901.78	358.426	12.438	-.492	12.448	-.02471	.689	-.07695	.30496	.31452	-.01412	.8
22031	92	649779.45	42901.40	358.395	12.395	-.208	12.396	-.03067	-.644	.03203	.24495	.24703	.00220	.8
22032	93	649791.94	42901.27	358.365	12.502	-.002	12.502	-.03161	-1.487	.13984	.15212	.20663	-.00488	.8
22033	94	649804.52	42901.27	358.331	12.678	.096	12.675	-.03709	-2.104	.15703	.02559	.15910	-.00680	.8
22034	95	649817.23	42901.29	358.290	12.816	.090	12.817	-.03042	-1.931	.16719	-.11104	.20070	.02087	.8
22035	96	649830.19	42901.20	358.270	13.009	-.126	13.009	-.00097	-1.176	.23047	-.19121	.29946	.03803	.8
22036	97	649843.38	42900.99	358.288	13.277	-.333	13.282	.02934	-.276	.27539	-.18984	.33489	.02300	.8
22037	98	649856.70	42900.61	358.329	13.559	-.509	13.569	.05421	.464	.22052	-.13583	.25953	.02612	.8
22038	99	649870.34	42900.07	358.397	13.734	-.603	13.748	.07372	.912	.08677	-.06936	.10993	.01270	.8
22039	100	649884.02	42899.45	358.477	13.729	-.644	13.744	.08006	1.163	-.02900	-.04247	.04965	-.00001	.8
22040	101	649897.79	42898.79	358.557	13.686	-.689	13.702	.08135	1.439	-.00604	-.02888	.02575	.00650	.8
22041	102	649911.50	42898.11	358.643	13.716	-.694	13.733	.08439	1.540	.02617	.00217	.02626	-.00459	.8
22042	103	649925.20	42897.43	358.724	13.737	-.645	13.754	.06923	1.579	-.02978	-.00161	.02983	-.02566	.8
22043	104	649938.88	42896.73	358.762	13.664	-.697	13.682	.03603	1.703	-.11719	-.01177	.11778	-.04076	.8
22044	105	649952.39	42896.01	358.768	13.502	-.708	13.521	.00254	1.800	-.17534	-.00820	.17558	-.02621	.8
22045	106	649965.88	42895.38	358.767	13.313	-.716	13.332	-.01881	1.859	-.16080	.00480	.16086	-.01769	.8
		(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)

Table A.10 Page Three, Interpolated Engine, Current, and Depth Data

TIME HHMMSS	SECS	STARBOARD ENGINE HP	SRPM	ERPM	PORT ENGINE HP	SRPM	ERPM	BOTH ENGINES HP	SRPM	ERPM	CURRENT X,FT/SEC	Y,FT/SEC	DEPTH,FT STERN	BOW
219 0	1	1571,10	220,00	763,40	1869,50	232,00	798,10	3440,60	225,00	780,75	-2,869	,201	31,0	40,0
219 1	2	1570,64	220,02	763,46	1870,57	232,00	798,10	3441,21	225,01	780,78	-2,869	,201	31,0	39,7
219 2	3	1570,18	220,03	763,52	1871,57	232,00	798,10	3441,75	225,02	780,81	-2,869	,201	31,1	39,5
219 3	4	1569,72	220,05	763,57	1872,55	232,00	798,10	3442,26	225,02	780,84	-2,869	,201	31,1	39,2
219 4	5	1569,26	220,07	763,63	1873,49	232,00	798,10	3442,75	225,03	780,87	-2,869	,201	31,2	39,0
219 5	6	1568,79	220,08	763,69	1874,41	232,00	798,10	3443,21	225,04	780,89	-2,869	,201	31,2	38,7
219 6	7	1568,33	220,10	763,75	1875,31	232,00	798,10	3443,64	225,05	780,92	-2,869	,201	31,2	38,5
219 7	8	1567,87	220,12	763,80	1876,17	232,00	798,10	3444,04	225,06	780,95	-2,869	,201	31,3	38,2
219 8	9	1567,41	220,13	763,86	1877,01	232,00	798,10	3444,42	225,07	780,98	-2,869	,201	31,3	38,0
219 9	10	1566,95	220,15	763,92	1877,81	232,00	798,10	3444,76	225,07	781,01	-2,869	,201	31,3	37,7
21910	11	1566,49	220,17	763,98	1878,59	232,00	798,10	3445,08	225,08	781,04	-2,869	,201	31,4	37,5
21911	12	1566,03	220,18	764,04	1879,35	232,00	798,10	3445,37	225,09	781,07	-2,869	,201	31,4	37,3
21912	13	1565,56	220,20	764,09	1880,07	232,00	798,10	3445,64	225,10	781,10	-2,869	,201	31,4	37,0
21913	14	1565,10	220,22	764,15	1880,77	232,00	798,10	3445,87	225,11	781,13	-2,869	,201	31,5	36,8
21914	15	1564,64	220,23	764,21	1881,44	232,00	798,10	3446,08	225,12	781,15	-2,869	,201	31,5	36,6
21915	16	1564,18	220,25	764,27	1882,08	232,00	798,10	3446,26	225,12	781,18	-2,869	,201	31,5	36,4
21916	17	1563,72	220,27	764,33	1882,70	232,00	798,10	3446,41	225,13	781,21	-2,869	,201	31,6	36,2
21917	18	1563,25	220,28	764,38	1883,28	232,00	798,10	3446,54	225,14	781,24	-2,869	,201	31,6	35,9
21918	19	1562,79	220,30	764,44	1883,84	232,00	798,10	3446,63	225,15	781,27	-2,869	,201	31,6	35,7
21919	20	1562,33	220,32	764,50	1884,37	232,00	798,10	3446,70	225,16	781,30	-2,869	,201	31,6	35,5
21920	21	1561,87	220,33	764,56	1884,87	232,00	798,10	3446,74	225,17	781,33	-2,869	,201	31,7	35,3
21921	22	1561,40	220,35	764,61	1885,35	232,00	798,10	3446,75	225,17	781,36	-2,869	,201	31,7	35,1
21922	23	1560,94	220,37	764,67	1885,80	232,00	798,10	3446,74	225,18	781,39	-2,869	,201	31,7	34,9
21923	24	1560,48	220,38	764,73	1886,22	232,00	798,10	3446,70	225,19	781,42	-2,869	,201	31,7	34,7
21924	25	1560,02	220,40	764,79	1886,61	232,00	798,10	3446,63	225,20	781,44	-2,869	,201	31,8	34,6
21925	26	1559,55	220,42	764,85	1886,97	232,00	798,10	3446,53	225,21	781,47	-2,869	,201	31,8	34,4
21926	27	1559,09	220,43	764,90	1887,31	232,00	798,10	3446,40	225,22	781,50	-2,869	,201	31,8	34,2
21927	28	1558,63	220,45	764,96	1887,62	232,00	798,10	3446,25	225,22	781,53	-2,869	,201	31,8	34,0
21928	29	1558,16	220,47	765,02	1887,90	232,00	798,10	3446,06	225,23	781,56	-2,869	,201	31,8	33,8
21929	30	1557,70	220,48	765,08	1888,15	232,00	798,10	3445,85	225,24	781,59	-2,869	,201	31,8	33,7
21930	31	1557,24	220,50	765,14	1888,38	232,00	798,10	3445,62	225,25	781,62	-2,869	,201	31,9	33,5
21931	32	1556,77	220,52	765,19	1888,58	232,00	798,10	3445,35	225,26	781,65	-2,869	,201	31,9	33,3
21932	33	1556,31	220,53	765,25	1888,75	232,00	798,10	3445,06	225,27	781,68	-2,869	,201	31,9	33,2
21933	34	1555,85	220,55	765,31	1888,89	232,00	798,10	3444,74	225,27	781,70	-2,869	,201	31,9	33,0
21934	35	1555,38	220,57	765,37	1889,00	232,00	798,10	3444,38	225,28	781,73	-2,869	,201	31,9	32,9
21935	36	1554,92	220,58	765,42	1889,09	232,00	798,10	3444,01	225,29	781,76	-2,869	,201	31,9	32,7
21936	37	1554,46	220,60	765,48	1889,15	232,00	798,10	3443,61	225,30	781,79	-2,869	,201	32,0	32,6
21937	38	1553,99	220,62	765,54	1889,18	232,00	798,10	3443,17	225,31	781,82	-2,869	,201	32,0	32,4
21938	39	1553,53	220,63	765,60	1889,18	232,00	798,10	3442,71	225,32	781,85	-2,869	,201	32,0	32,3
21939	40	1553,06	220,65	765,66	1889,16	232,00	798,10	3442,22	225,32	781,88	-2,869	,201	32,0	32,1
21940	41	1552,60	220,67	765,71	1889,11	232,00	798,10	3441,71	225,33	781,91	-2,869	,201	32,0	32,0
21941	42	1552,14	220,68	765,77	1889,03	232,00	798,10	3441,16	225,34	781,94	-2,869	,201	32,0	31,9
21942	43	1551,67	220,70	765,83	1888,92	232,00	798,10	3440,59	225,35	781,96	-2,869	,201	32,0	31,7
21943	44	1551,21	220,72	765,89	1888,78	232,00	798,10	3439,99	225,36	781,99	-2,869	,201	32,0	31,6
21944	45	1550,74	220,73	765,94	1888,62	232,00	798,10	3439,36	225,37	782,02	-2,869	,201	32,0	31,5
21945	46	1550,28	220,75	766,00	1888,43	232,00	798,10	3438,71	225,37	782,05	-2,869	,201	32,0	31,4
21946	47	1549,81	220,77	766,06	1888,21	232,00	798,10	3438,03	225,38	782,08	-2,869	,201	32,0	31,3
21947	48	1549,35	220,78	766,12	1887,97	232,00	798,10	3437,32	225,39	782,11	-2,869	,201	32,0	31,1
21948	49	1548,88	220,80	766,18	1887,69	232,00	798,10	3436,58	225,40	782,14	-2,869	,201	32,0	31,0
21949	50	1548,42	220,82	766,23	1887,39	232,00	798,10	3435,81	225,41	782,17	-2,869	,201	32,0	30,9
21950	51	1547,95	220,83	766,29	1887,06	232,00	798,10	3435,02	225,42	782,20	-2,869	,201	32,0	30,8
21951	52	1547,49	220,85	766,35	1886,70	232,00	798,10	3434,19	225,42	782,22	-2,869	,201	32,0	30,7
21952	53	1547,02	220,87	766,41	1886,32	232,00	798,10	3433,34	225,43	782,25	-2,869	,201	32,0	30,6
21953	54	1546,56	220,88	766,47	1885,91	232,00	798,10	3432,47	225,44	782,28	-2,869	,201	32,0	30,5
21954	55	1546,09	220,90	766,52	1885,47	232,00	798,10	3431,56	225,45	782,31	-2,869	,201	32,0	30,5
21955	56	1545,63	220,92	766,58	1885,00	232,00	798,10	3430,63	225,46	782,34	-2,869	,201	32,0	30,4
21956	57	1545,16	220,93	766,64	1884,50	232,00	798,10	3429,66	225,47	782,37	-2,869	,201	32,0	30,3
21957	58	1544,70	220,95	766,70	1883,98	232,00	798,10	3428,67	225,47	782,40	-2,869	,201	32,0	30,2
21958	59	1544,23	220,97	766,75	1883,43	232,00	798,10	3427,66	225,48	782,43	-2,869	,201	32,0	30,1
21959	60	1543,77	220,98	766,81	1882,85	232,00	798,10	3426,61	225,49	782,46	-2,869	,201	32,0	30,1
220 0	61	1543,30	221,00	766,87	1882,24	232,00	798,10	3425,54	225,50	782,48	-2,869	,201	32,0	30,0
220 1	62	1542,70	221,02	766,96	1880,79	232,00	798,10	3423,48	225,51	782,53	-2,869	,201	31,9	30,0
220 2	63	1542,10	221,05	767,04	1879,33	232,00	798,10	3421,43	225,52	782,57	-2,869	,201	31,9	30,1
220 3	64	1541,50	221,07	767,13	1877,88	232,00	798,10	3419,38	225,54	782,61	-2,869	,201	31,8	30,1
220 4	65	1540,91	221,10	767,21	1876,43	232,00	798,10	3417,34	225,55	782,65	-2,869	,201	31,7	30,2
220 5	66	1540,33	221,12	767,29	1874,97	232,00	798,10	3415,30	225,56	782,70	-2,869	,201	31,7	30,2
220 6	67	1539,75	221,14	767,37	1873,52	232,00	798,10	3413,27	225,57	782,74	-2,869	,201	31,6	30,2
220 7	68	1539,17	221,17	767,45	1872,06	232,00	798,10	3411,24	225,58	782,78	-2,869	,201	31,6	30,3
220 8	69	1538,60	221,19	767,53	1870,61	232,00	798,10	3409,21	225,60	782,82	-2,869	,201	31,5	30,3
220 9	70	1538,04	221,21	767,61	1869,16	232,00	798,10	3407,19	225,61	782,86	-2,869	,201	31,4	30,4
22010	71	1537,47	221,24	767,69	1867,70	232,00	798,10	3405,18	225,62	782,89	-2,869	,201	31,4	30,4
22011	72	1536,92	221,26	767,77	1866,25	232,00	798,10	3403,17	225,63	782,93	-2,869	,201	31,3	30,4
22012	73	1536,36	221,28	767,84	1864,80	232,00	798,10	3401,16	225,64	782,97	-2,869	,201	31,3	30,5
22013	74	1535,81	221,30	767,92	1863,34	232,00	798,10	3399,16	225,65	783,01	-2,869	,201	31,2	30,5
22014	75	1535,27	221,32	767,99	1861,89	232,00	798,10	3397,16	225,66	783,05	-2,869	,201	31,2	30,6
22015	76	1534,73	221,34	768,06	1860,43	232,00	798,10	3395,17	225,67	783,08	-2,869	,201	31,1	30,6
22016	77	1534,20	221,36	768,13	1858,98	232,00	798,10	3393,18	225,68	783,12	-2,869	,201	31,1	30,6
22017	78	1533,67	221,38	768,21	1857,53	232,00	798,10	3391,19	225,69	783,15	-2,869	,201	31,0	30,7
22018	79	1533,14	221,40	768,28	1856,07	232,00	798,10	3389,22	225,70	783,19	-2,869	,201	31,0	30,7
22019	80	1532,62	221,42	768,34	1854,62	232,00	798,10	3387,24	225,71	783,22	-2,869	,201	30,9	30,7
22020	81	1532,10	221,44	768,41	1853,17	232,00	798,10	3385,27	225,72	783,26	-2,869	,201	30,9	30,8
22021	82	1531,60	221,46	768,48	1851,71	232,00	798,10	3383,31	225,73	783,29	-2,869	,201	30,8	30,8
22022	83	1531,09	221,48	768,55	1850,26	232,00	798,10	3381,34	225,74	783,32	-2,869	,201	30,8	30,8
22023	84	1530,58	221,50	768,61	1848,81	232,00	798,10	3379,39	225,75	783,36	-2,869	,201	30,8	30,9
22024	85	1530,08	221,52	768,67	1847,35	232,00	798,10	3377,44	225,76	783,39	-2,869	,201	30,7	30,9
22025	86	1529,59	221,54	768,74	1845,90	232,00	798,10	3375,49	225,77	783,42	-2,869	,201	30,7	31,0
22026	87	1529,10	221,56	768,80	1844,45	232,00	798,10	3373,55	225,78	783,45	-2,869	,201	30,6	31,0
22027	88	1528,62	221,57	768,86	1842,99	232,00	798,10	3371,61	225,79	783,48	-2,869	,201	30,6	31,0
22028	89	1528,14	221,59	768,92	1841,54	232,00	798,10	3369,68	225,80	783,51	-2,869	,201	30,6	31,1
22029	90	1527,66	221,61	768,98	1840,08	232,00	798,10	3367,75	225,80	783,54	-2,869	,201	30,5	31,1
22030	91	1527,19	221,62	769,04	1838,63	232,00	798,10	3365,82	225,81	783,57	-2,869	,201	30,5	31,1
22031	92	1526,73	221,64	769,10	1837,18	232,00	798,10	3363,90	225,82	783,60	-2,869	,201	30,5	31,2
22032	93	1526,27	221,66	769,15	1835,72	232,00	798,10	3361,99	225,83	783,63	-2,869	,201	30,4	31,2
22033	94	1525,81	221,67	769,21	1834,27	232,00	798,10	3360,08	225,84	783,65	-2,869	,201	30,4	31,2
22034	95	1525,36	221,69	769,26	1832,82	232,00	798,10	3358,17	225,84	783,68	-2,869	,201	30,4	31,3
22035	96	1524,91	221,70	769,32	1831,36	232,00	798,10	3356,27	225,85	783,71	-2,869	,201	30,3	31,3
22036	97	1524,46	221,72	769,37	1829,91	232,00	798,10	3354,38	225,86	783,73	-2,869	,201	30,3	31,3
22037	98	1524,03	221,73	769,42	1828,46	232,00	798,10	3352,48	225,87	783,76	-2,869	,201	30,3	31,4
22038	99	1523,59	221,75	769,47	1827,01	232,00	798,10	3350,60	225,87	783,79	-2,869	,201	30,3	31,4
22039	100	1523,16	221,76	769,52	1825,55	232,00	798,10	3348,71	225,88	783,81	-2,869	,201	30,2	31,4
22040	101	1522,74	221,78	769,57	1824,10	232,00	798,10	3346,83	225,89	783,83	-2,869	,201	30,2	31,4
22041	102	1522,32	221,79	769,62	1822,64	232,00	798,10	3344,96	225,90	783,86	-2,869	,201	30,2	31,5
22042	103	1521,90	221,80	769,66	1821,19	232,00	798,10	3343,09	225,90	783,88	-2,869	,201	30,2	31,5
22043	104	1521,49	221,82	769,71	1819,74	232,00	798,10	3341,23	225,91	783,90	-2,869	,201	30,2	31,5
22044	105	1521,09	221,83	769,75	1818,28	232,00	798,10	3339,37	225,92	783,93	-2,869	,201	30,1	31,6
22045	106	1520,68	221,84	769,80	1816,83	232,00	798,10	3337,51	225,92	783,95	-2,869	,201	30,1	31,6
		(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)

Table A.11 Page Four, Interpolated Distance-Off Data

TIME		F.H. DIST OFF,FT.		BOW DIST. OFF,FT.	
HHMMSS	SECS	W/B BANK	E/W BANK	W/B BANK	E/W BANK
219 0	1	1200.50	1654.50	1273.50	2001.50
219 1	2	1197.10	1658.30	1269.68	1994.00
219 2	3	1193.75	1662.04	1265.50	1986.59
219 3	4	1190.44	1665.74	1261.59	1979.26
219 4	5	1187.18	1669.38	1257.70	1972.02
219 5	6	1183.96	1672.97	1253.87	1964.86
219 6	7	1180.79	1676.52	1250.09	1957.78
219 7	8	1177.67	1680.01	1246.35	1950.79
219 8	9	1174.59	1683.45	1242.67	1943.88
219 9	10	1171.55	1686.85	1239.03	1937.05
21910	11	1168.56	1690.19	1235.44	1930.31
21911	12	1165.62	1693.48	1231.89	1923.65
21912	13	1162.72	1696.72	1228.40	1917.08
21913	14	1159.87	1699.91	1224.95	1910.59
21914	15	1157.06	1703.05	1221.55	1904.18
21915	16	1154.30	1706.14	1218.20	1897.86
21916	17	1151.58	1709.18	1214.90	1891.62
21917	18	1148.91	1712.17	1211.64	1885.46
21918	19	1146.28	1715.11	1208.44	1879.39
21919	20	1143.70	1718.00	1205.28	1873.40
21920	21	1141.17	1720.83	1202.17	1867.50
21921	22	1138.68	1723.62	1199.10	1861.68
21922	23	1136.23	1726.36	1196.09	1855.94
21923	24	1133.83	1729.04	1193.12	1850.29
21924	25	1131.48	1731.68	1190.20	1844.72
21925	26	1129.17	1734.27	1187.33	1839.23
21926	27	1126.91	1736.80	1184.50	1833.83
21927	28	1124.69	1739.29	1181.73	1828.51
21928	29	1122.52	1741.72	1179.00	1823.28
21929	30	1120.39	1744.10	1176.32	1818.13
21930	31	1118.31	1746.44	1173.69	1813.06
21931	32	1116.28	1748.72	1171.10	1808.08
21932	33	1114.29	1750.95	1168.57	1803.18
21933	34	1112.34	1753.14	1166.08	1798.36
21934	35	1110.44	1755.27	1163.64	1793.63
21935	36	1108.59	1757.35	1161.24	1788.98
21936	37	1106.78	1759.38	1158.90	1784.42
21937	38	1105.02	1761.36	1156.60	1779.94
21938	39	1103.30	1763.29	1154.35	1775.54
21939	40	1101.63	1765.17	1152.15	1771.23
21940	41	1100.00	1767.00	1150.00	1767.00
21941	42	1098.42	1768.78	1147.89	1762.85
21942	43	1096.88	1770.51	1145.84	1758.79
21943	44	1095.39	1772.19	1143.83	1754.81
21944	45	1093.95	1773.81	1141.87	1750.92
21945	46	1092.55	1775.39	1139.95	1747.11
21946	47	1091.19	1776.92	1138.09	1743.38
21947	48	1089.88	1778.39	1136.27	1739.74
21948	49	1088.62	1779.82	1134.50	1736.18
21949	50	1087.40	1781.20	1132.78	1732.70
21950	51	1086.23	1782.52	1131.10	1729.31
21951	52	1085.10	1783.80	1129.48	1726.00
21952	53	1084.02	1785.02	1127.90	1722.78
21953	54	1082.98	1786.19	1126.37	1719.64
21954	55	1081.99	1787.32	1124.89	1716.58
21955	56	1081.05	1788.39	1123.45	1713.61
21956	57	1080.15	1789.41	1122.07	1710.72
21957	58	1079.29	1790.39	1120.73	1707.91
21958	59	1078.48	1791.31	1119.44	1705.19
21959	60	1077.72	1792.18	1118.19	1702.55
220 0	61	1077.00	1793.00	1117.00	1700.00
220 1	62	1078.27	1792.07	1117.12	1699.73
220 2	63	1079.53	1791.15	1117.24	1699.47
220 3	64	1080.76	1790.23	1117.37	1699.22
220 4	65	1081.97	1789.32	1117.51	1698.97
220 5	66	1083.16	1788.42	1117.65	1698.74
220 6	67	1084.33	1787.53	1117.79	1698.51
220 7	68	1085.48	1786.64	1117.94	1698.30
220 8	69	1086.61	1785.76	1118.09	1698.09
220 9	70	1087.72	1784.89	1118.25	1697.90
22010	71	1088.81	1784.03	1118.42	1697.71
22011	72	1089.87	1783.17	1118.59	1697.53
22012	73	1090.92	1782.32	1118.76	1697.36
22013	74	1091.95	1781.49	1118.94	1697.20
22014	75	1092.95	1780.66	1119.12	1697.05
22015	76	1093.94	1779.81	1119.31	1696.91
22016	77	1094.90	1778.99	1119.51	1696.77
22017	78	1095.85	1778.18	1119.71	1696.65
22018	79	1096.77	1777.37	1119.91	1696.53
22019	80	1097.67	1776.57	1120.12	1696.43
22020	81	1098.56	1775.78	1120.33	1696.33
22021	82	1099.42	1774.99	1120.55	1696.25
22022	83	1100.26	1774.21	1120.78	1696.17
22023	84	1101.08	1773.44	1121.01	1696.10
22024	85	1101.88	1772.68	1121.24	1696.04
22025	86	1102.66	1771.92	1121.48	1695.99
22026	87	1103.42	1771.17	1121.72	1695.95
22027	88	1104.16	1770.43	1121.97	1695.92
22028	89	1104.88	1769.70	1122.23	1695.89
22029	90	1105.57	1768.97	1122.49	1695.88
22030	91	1106.25	1768.25	1122.75	1695.87
22031	92	1106.91	1767.54	1123.02	1695.88
22032	93	1107.54	1766.83	1123.29	1695.89
22033	94	1108.16	1766.13	1123.57	1695.92
22034	95	1108.75	1765.44	1123.86	1695.95
22035	96	1109.33	1764.76	1124.15	1695.99
22036	97	1109.88	1764.08	1124.44	1696.04
22037	98	1110.41	1763.41	1124.74	1696.10
22038	99	1110.93	1762.75	1125.04	1696.17
22039	100	1111.42	1762.09	1125.35	1696.25
22040	101	1111.89	1761.44	1125.67	1696.33
22041	102	1112.34	1760.80	1125.99	1696.43
22042	103	1112.77	1760.17	1126.31	1696.53
22043	104	1113.18	1759.54	1126.64	1696.65
22044	105	1113.57	1758.92	1126.97	1696.77
22045	106	1113.94	1758.31	1127.31	1696.91
		(39)	(40)	(41)	(42)

APPENDIX B.

Horsepower and RPM Measurements

The measurements of shaft horsepower (SHP), shaft revolutions per minute (SRPM), brake horsepower (BHP), and engine revolutions per minute (ERPM) obtained by Dravo during the trials are contained in this section. SHP is a constant 98 percent of BHP and SRPM a constant 28.82 percent of ERPM.

All values in the following tables are rounded to the nearest whole number. The recorded time in hours and minutes refers to local Baton Rouge time on November 23, 1976 and corresponds to the clock times used throughout the report.

Table B.1 Trial Run 1

Straight Course, Full Power, Upriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
2:18	230	1857	798	1895								
:19	230	1870	798	1907	220	1571	763	1603	225	3441	781	3511
:20	230	1882	798	1921	221	1543	767	1575	226	3426	782	3495
:21	230	1795	798	1832	222	1515	770	1546	226	3310	784	3378
:22	230	1708	798	1743	222	1504	770	1534	226	3211	784	3277
:23	228	1693	791	1727	222	1492	770	1522	225	3185	781	3250
:24	226	1678	784	1712	222	1500	770	1530	224	3178	777	3243
:25	228	1681	791	1715	222	1508	770	1538	225	3188	781	3253
:26	228	1681	791	1715	222	1461	770	1490	225	3141	781	3205
:27	228	1680	791	1715	221	1466	767	1496	225	3146	779	3210
:28	229	1682	795	1716	220	1471	763	1501	225	3152	779	3217
:29	230	1683	798	1717	220	1463	763	1493	225	3146	781	3210
:30	228	1680	791	1714	220	1455	763	1485	224	3135	777	3199
:31	228	1668	791	1702	220	1440	763	1469	224	3107	777	3171
:32	228	1674	791	1708	220	1455	763	1485	224	3129	777	3193
:33	228	1680	791	1714	221	1462	767	1492	225	3142	779	3206
:34	228	1692	791	1727	222	1469	770	1499	225	3161	781	3225
:35	227	1691	788	1725	220	1455	763	1485	224	3146	776	3210
:36	226	1689	784	1724	220	1459	763	1489	223	3149	774	3213
:37					220	1463	763	1493				

Table B.2 Trial Run 2

Straight Course, Full Power, Downriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
3:00	222	1776	770	1813								
:01	224	1762	777	1798	222	1532	770	1563	223	3294	774	3361
:02	226	1747	784	1783	221	1509	767	1540	224	3256	776	3323
:03	226	1705	784	1739	220	1487	763	1517	223	3191	774	3257
:04	226	1662	784	1696	220	1495	763	1525	223	3157	774	3221
:05	227	1676	788	1710	220	1503	763	1533	224	3178	776	3243
:06	228	1689	791	1724	220	1491	763	1521	224	3180	777	3245
:07	226	1662	784	1696	220	1479	763	1509	223	3141	774	3205
:08	228	1677	791	1711	220	1479	763	1509	224	3156	777	3220
:09	227	1663	788	1697	222	1485	770	1515	225	3148	779	3212
:10	226	1650	784	1683	221	1478	767	1508	224	3128	776	3192
:11	228	1652	791	1685	220	1471	763	1502	224	3123	777	3187

Table B.3 Trial Run 3

Straight Course, 3/4 Power, Upriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
3:41	202	1190	701	1214								
:42	203	1196	704	1220	198	1073	687	1095	201	2269	696	2316
:43	204	1202	708	1226	199	1086	691	1108	202	2287	699	2334
:44	204	1212	708	1237	200	1098	694	1121	202	2311	701	2358
:45	204	1212	708	1237	200	1084	694	1106	202	2297	701	2344
:46	204	1212	708	1237	200	1077	694	1099	202	2290	701	2337
:47	205	1218	711	1243	200	1070	694	1092	203	2288	703	2335
:48	206	1224	715	1249	200	1070	694	1092	203	2294	704	2341
:49	204	1201	708	1226	200	1070	694	1092	202	2271	701	2318
:50	204	1223	708	1248	200	1070	694	1092	202	2293	701	2340
:51	205	1224	711	1254	200	1077	694	1099	203	2306	703	2353
:52	206	1235	715	1260	200	1077	694	1099	203	2312	704	2359
:53	208	1247	722	1272	200	1077	694	1099	204	2324	708	2372
:54	206	1240	715	1266	200	1077	694	1099	203	2318	704	2365
:55	204	1234	708	1259								

Table B.4 Trial Run 4

Straight Course, 1/2 Power, Downriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
4:23	174	827	604	844								
:24	174	812	605	828	167	641	579	654	171	1452	592	1482
:25	175	198	606	814	167	647	579	660	171	1444	593	1474
:26	175	783	607	799	167	652	579	666	171	1436	593	1465
:27	175	779	607	794	167	658	579	672	171	1437	593	1466
:28	175	774	607	789	167	655	579	669	171	1429	593	1458
:29	175	774	607	789	167	653	579	666	171	1426	593	1455
:30	175	774	607	789	167	653	579	666	171	1426	593	1455
:31	175	773	607	789	167	652	579	666	171	1426	593	1455
:32	175	773	607	789	167	653	579	666	171	1426	593	1455
:33	175	773	607	789	167	659	579	672	171	1432	593	1461
:34	175	773	607	789	167	653	579	666	171	1426	593	1455
:35	175	773	607	789								

Table B.5 Trial Run 5

Zig-Zag, Full Power, Upriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
5:11	228	1753	791	1788								
:12	227	1745	788	1781	222	1534	770	1565	225	3279	779	3346
:13	226	1737	784	1773	221	1519	767	1550	224	3257	776	3323
:14	226	1719	784	1754	220	1504	763	1536	223	3224	774	3290
:15	226	1701	784	1736	220	1497	763	1528	223	3198	774	3263
:16	228	1704	791	1739	220	1489	763	1520	224	3193	777	3259
:17	227	1709	788	1744	222	1471	770	1501	225	3180	779	3245
:18	226	1713	784	1748	221	1457	767	1487	224	3170	776	3235
:19	228	1716	791	1751	220	1442	763	1472	224	3159	777	3223
:20	228	1704	791	1739	220	1474	763	1504	224	3178	777	3242
:21	228	1692	791	1726	220	1489	763	1520	224	3181	777	3246
:22	228	1740	791	1776	220	1505	763	1536	224	3245	777	3311
:23	228	1655	791	1689	220	1489	763	1520	224	3144	777	3208
:24	229	1680	795	1715	222	1558	770	1590	226	3238	782	3304
:25	230	1706	798	1741	221	1519	767	1550	226	3226	782	3291
:26	229	1705	795	1740	220	1481	763	1512	225	3187	779	3252
:27	228	1704	791	1739	219	1502	760	1532	224	3206	776	3272
:28	229	1731	795	1766	218	1522	756	1553	224	3253	776	3319
:29	230	1758	798	1793	217	1469	753	1499	224	3226	776	3292
:30					216	1416	750	1445				

Table B.6 Trial Run 6

Steady Turn, 1/2 Power, Upriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
5:41	176	860	611	878								
:42	176	856	611	873	174	680	604	694	175	1536	607	1568
:43	176	842	611	859	173	701	600	715	175	1543	606	1575
:44	178	833	618	850	172	721	597	736	175	1554	607	1585
:45	178	861	618	879	174	773	604	788	176	1634	611	1667
:46	178	890	618	908	172	767	597	782	175	1657	607	1690
:47	177	890	614	908	170	761	590	776	174	1651	602	1684
:48	176	889	611	898	171	762	593	778	174	1642	602	1676
:49	176	785	611	801	172	763	597	779	174	1549	604	1580
:50					170	671	590	684				

Table B.8 Trial Run 8

Zig-Zag, Full Power, Downriver

	Port Engine				Starboard Engine				Both Engines			
Time	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP	SRPM	SHP	ERPM	BHP
6:39	226	1749	784	1785								
:40	228	1655	791	1688	220	1513	763	1543	224	3167	777	3232
:41	228	1679	791	1714	222	1464	770	1493	225	3143	781	3207
:42	228	1649	791	1682	222	1511	770	1541	225	3159	781	3224
:43	228	1679	791	1713	223	1490	772	1521	225	3169	782	3234
:44	228	1673	791	1707	223	1470	774	1500	226	3143	782	3207
:45	228	1667	791	1701	222	1449	769	1478	225	3115	780	3179
:46	228	1692	791	1726	220	1427	763	1456	224	3119	777	3182
:47	228	1728	791	1763	220	1458	763	1488	224	3186	777	3251
:48	228	1710	791	1745	220	1551	763	1583	224	3261	777	3328
:49	228	1691	791	1756	221	1531	767	1563	225	3223	779	3288
:50					222	1511	770	1542				

REFERENCES

[1] Motorola, "The Mini-Ranger III Horizontal Positioning System", Government Electronics Division, Scottsdale, Arizona.

[2] Dravo Corporation, "Towboat 'Exxon Memphis' River Trial Report", prepared for Exxon Company, Pittsburgh, Pa., January 1977.

[3] Electro-Motive Division, "Application Data for General Motors Series 645 Marine Diesel Engines", General Motors, La Grange, Ill. April 1972.

[4] Corps of Engineers, "Flood Control and Navigation Maps of of the Mississippi River, Cairo, Illinois to the Gulf of Mexico", 42nd Ed., Vicksburg, Miss., 1974.

[5] U.S. Department of Commerce, Coast and Geodetic Survey, "Field Geographic Positions (G-14600)", Unadjusted field survey data furnished by the National Geodetic Survey, Rockville, Md. in December 1976.

[6] U.S. Department of Commerce, Coast and Geodetic Survey, "Plane Coordinate Projection Tables, Louisiana (Lambert)", Special Publication No. 291, GPO, Washington, 1962.

[7] Breed, C.B. and Hosmer, G.L., Higher Surveying, Vol. II, Revised by Bone, A.J., Eighth Edition, John Wiley & Sons, Inc., New York.

[8] Schulz, R.M., "River Tow Behavior in Waterways", Vol. 1-3, R M Schulz Associates, Lafayette, California, December 1976.

[9] S.N.A.M.E., "Nomenclature for Treating the Motion of a Submerged Body Through a Fluid", Technical and Research Bulletin No. 1-5, New York, N.Y., March 1968.

[10] Corps of Engineers, "Mississippi River Hydrographic Survey, 1973-1975, Black Hawk, La. to Head of Passes, La.", U.S. Army Engineer District, New Orleans, La., June 1976.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Schulz, Roger M

River tow behavior in waterways; Report 1: Exxon test program / by Roger M. Schulz, R. M. Schulz Associates, Lafayette, Calif. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

xiii, 134 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; H-78-17, Report 1)

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References: p. 133-134.

1. Exxon test program. 2. Towboats. 3. Tows and towing. 4. Waterways (Transportation). I. Schulz (R. M.) Associates. II. United States. Army. Corps of Engineers. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; H-78-17, Report 1.

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